INSTRUCTION BOOK

MODEL 33A/1

RF ADMITTANCE BRIDGE

(Serial No. 282 & above)

BOONTON ELECTRONICS CORPORATION

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SECTION I

GENERAL DESCRIPTION

The Model 33A/33B RF Admittance Bridge employs a new bridge circuit in which the r-f conductance (or resistance) is measured in terms of a ratio of capacitance. The circuit is shown in Figure 1 and is comprised of a balanced transformer, two fixed resistors, and two capacitors, one of which is variable. The measuring circuit configuration and attendant balance equations allow the circuit parameters to be selected for optimum performance at radio frequencies. The resistance values are such that they exhibit a minimum of residual reactance and the capacitors are designed for minimum inductance and loss.

Because the bridge basically measures conductance, additional circuitry is required for the substitution method of measuring the susceptive component of a complex admittance. This circuitry consists of an internal variable capacitor which resonates at the measuring frequency with an external inductor, hereafter referred to as the work coil. Thus, susceptance is measured by the extent to which the parallel resonant circuit is detuned; conductance of the test specimen is determined by the ratio of the bridge capacitors.

The equations for balance are:

$$R_p = \frac{R}{(C/C_R - 1} \quad \text{or,} \quad G_p = \frac{(C/CR) - 1}{R} \qquad (1)$$

and,

$$C_p = C_{S_2} - C_{S_1}$$

From the circuit of figure1-1, Equation 1 would appear to yield the total conductance of the test specimen plus the equivalent conductance of the parallel circuit at resonance.

The loss of the resonant circuit, however, which is primarily that of the work coil, is negated by the simple addition of a variable capacitor in series with the calibrated variable capacitor, C_R. This additional capacitor provides a means for zeroing the conductance control when using inductors of different Q's. The range of this control is such that the bridge may be balanced for zero conductance provided the Q of the work coil is 50 or greater.

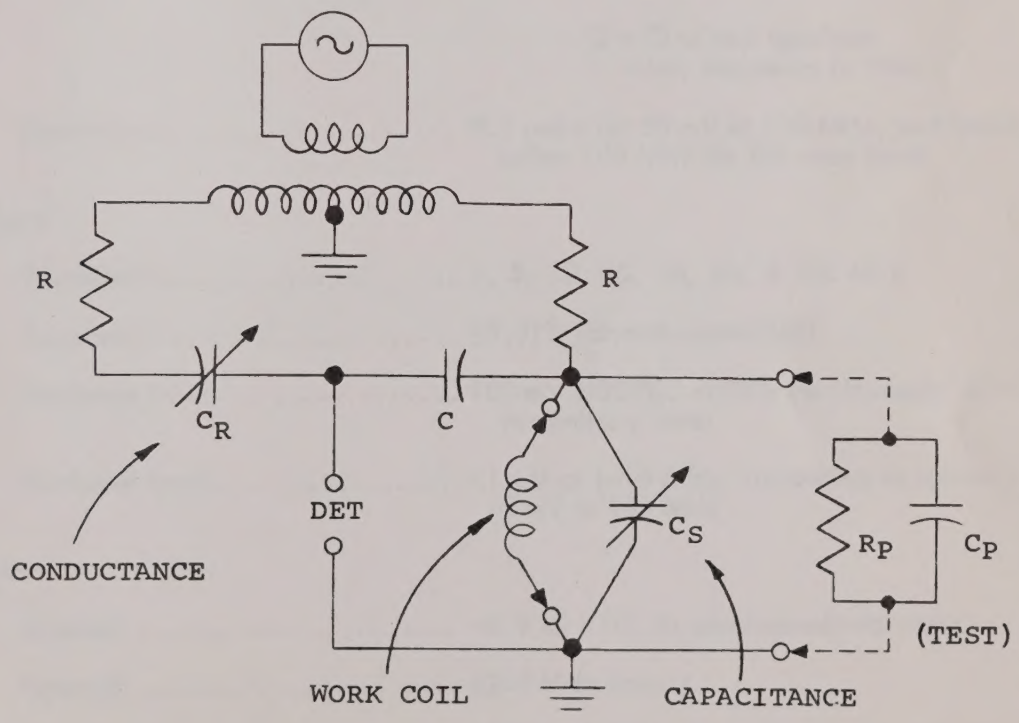


Figure 1-1

Bridge Circuit, Model 33A

SECTION 11

SPECIFICATIONS

Capacitance:

Range ..... 150 pF at 1 - 50 MHz, and 30 pF at 100 MHz

Accuracy ..... $\pm(1\% + \frac{f}{100}\% + 0.05\text{ pF})$ at 0 - 10 pF, and

$\pm(0.3\% + \frac{f}{100}\% + 0.12\text{ pF})$ at 10 - 150 pF, where

f = test frequency in MHz

Resolution ..... 0.02 pF for 50 mV at 1 MHz, and better above 1 MHz for the same level

Conductance:

Range ..... 0 to 25,000 μmhos

Accuracy ..... $\pm\ (2\% + \frac{Qf}{1000}\% + 0.5\ \mu\text{mho})$, where

Q = Q of test specimen
f = test frequency in MHz

Resolution ..... 0.5 μmho for 50 mV at 100 MHz, and better below 100 MHz for the same level

Test Signal:

Frequencies ..... 1, 5, 10, 20, 30, 50, & 100 MHz

Accuracy ..... ±0.01% (crystal controlled)

Maximum level ..... 100 mV (+300%, -10%); continuously variable to minimum level

Minimum level ..... <1 mV at 1-10 MHz, increasing to approx. 5 mV at 100 MHz

DC Bias:

Internal ..... -6 V to + 100 V; continuously variable

External ..... ±250 V dc (max.)

Power Requirements ..... 105 - 125 V (or 210 - 250 V), 50 - 60 Hz

Power Consumption ..... 45 watts

Weight ..... 33 lb.

Dimensions ..... 10 1/2" high, 20 1/2" wide, 12" deep

SECTION III

OPERATING PROCEDURE

3.1 INITIAL SETUP

3.1.1 Connect the power cable to an ac outlet of 105 to 125 volts, 50/60 cps. Turn the instrument on and allow a warm-up period of at least one hour. In order to minimize drift, remove the work coils from their case and place them atop the instrument for temperature stabilization during the warm-up period.

3.1.2 Set the DC BIAS switch to the OFF position and turn the RF LEVEL and SENSITIVITY controls to midposition. Set the FREQUENCY MC switch to the desired test frequency.

3.1.3 Refer to Table 3-1 for selection of the proper work coil, and insert the work coil in the three-terminal receptacle on top of the instrument. Tighten the set screws to insure stable contact.

Table 3-1

Frequency	Capacitance Range	CAPACITANCE Control Setting	CONDUCTANCE Control Setting	Work Coil Designation
1 - 30 Mc	150 pF	0 pF	0 μmho	Use coil marked for test freq.
50 Mc	150 pF	0 pF	0 μmho	6
100 Mc	30 pF	120 pF	0 μmho	7

3.1.4 Refer to Table 3-1 and adjust the CAPACITANCE and CONDUCTANCE controls to the settings required. Check that the knurled nuts on the HI and GND binding posts are fully seated and balance the bridge by adjusting the C ZERO and G ZERO controls until the NULL INDICATOR reads minimum. If maximum sensitivity is required, during 1 Mc measurements a meter reading of approximately 10 is normal.

NOTE: 1. If bridge balance cannot be accomplished as outlined, the Work Coil may be misadjusted. In this case, set the C Zero control to the center of its range, then alternately adjust the G Zero control and the Work Coil slug for bridge balance.

2. The work coil inductance may be varied to provide a capacitance balance at other than the specified settings without affecting the accuracy of the bridge. The correction curves are valid for the specified settings only.

3.2 MEASUREMENT

3.2.1 Connect the test specimen to the HI and GND binding posts on top of the instrument. Lead lengths must be kept at an absolute minimum - less than 1/8 inch for best accuracy. The binding post on the right is at ground potential. The left post is above ground and may be biased by either the internal or an external power supply.

3.2.2 If internal d-c bias is desired, the voltage applied to the test may be measured by connecting an appropriate d-c voltmeter (ungrounded) to the METER terminals. The sensitivity of the meter should be at least 20,000 ohms/volt. Removal of the meter will cause the bias voltage to rise because of the high output resistance (approx. 15 K) of the supply. Therefore, the internal d-c supply is a voltage source with the short circuit current limited to 6 mA. External bias to ±250 volts may be applied through front panel terminals but must be externally monitored. The short circuit current in this case will be limited by the resistance of the internal wiring (approx. 0.7 ohms) and the resistance of the Work Coil in use. See Warning, page 3-4.

3.2.3 The RF LEVEL control provided on the front panel may be adjusted for specified r-f test level. The test voltage must be measured across the test terminals with a suitable r-f millivoltmeter (i.e., BEC 91CA RF Voltmeter). The voltage should be measured after the bridge is balanced with the test specimen and the r-f voltmeter connected. This same voltage will appear across the test

specimen upon re-balancing the bridge with the voltmeter removed. The minimum RF level varies from approximately 5 mV at 100 Mc to less than 1 mV at 1 Mc. To further decrease the test voltage, a 50 ohm pad may be inserted at the BNC connector of the bridge transformer lead. For the case where the R.F. Level control must be able to provide a 1 mV test level at all frequencies, the Model 33-15A Attenuator may be installed. This device has a frequency response which provides the optimum max. to min. ratio at each frequency, the maximum available R.F. level being relatively unaffected at the lower frequencies.

3.2.4 With the test specimen connected, alternately adjust the CAPACITANCE dial and the CONDUCTANCE dial for minimum null indicator deflection.

3.2.5 The capacitance of the unknown is:

$$C_p = C_{d_2} - C_{d_1} + C_c$$

where

C_{d_1} = initial setting of CAPACITANCE dial. See Table I.

C_{d_2} = final setting of CAPACITANCE dial for bridge balance with the unknown connected.

C_c* = correction applied to C_{d_2}. See Figure 3-2.

3.2.6 The conductance of the test specimen is:

$$G_p = G_d + G_c$$ (See Note Page 3-5)

where

G_d = final setting of CONDUCTANCE dial for bridge balance with the unknown connected.

G_c*= correction applied to G_d at 20, 30, 50, and 100 Mc only. See Figure 3-2.

*NOTE: The corrections C_c and G_c are based on the assumption that the device to be measured is connected to the HI and GND posts with 1/8 inch leads. If a modified configuration is required which reduces the inductive loop, the capacitance correction indicated by Figure 3-2 will be more positive and the magnitude of the conductance correction will be reduced.

WARNING: With the BIAS switch in the EXTERNAL position, never apply an instantaneous voltage of more than 100 V.D.C. to the EXTERNAL binding posts unless a protective resistor (R=10 x bias voltage) is inserted in series with the hot lead. Resistive protection is recommended whenever the measurement will allow. To apply external bias of between 100 and 250 V.D.C. without resistive protection, use an adjustable power supply and set the voltage to the desired level after connection to the 33A EXTERNAL binding posts. Always adjust the external power supply for less than 100 V.D.C. before throwing the D.C. BIAS switch to or from the EXTERNAL position. Never short the HI and GND binding posts (top of instrument). Damage to the bridge section components will result when (1) the protective resistor is used but the voltage is greater than 100 V.D.C., (2) the protective resistor is not used and the current exceeds 200 milliamperes.

3.3 EXAMPLE MEASUREMENT

3.3.1 An 18 pF capacitor is to be measured at 100 Mc. Refer to Table 3-1 to establish the initial balance conditions. Work Coil 7 is required. The CAPACITANCE dial is set to 120 pF and the CONDUCTANCE dial is set to 0 μmho.

After completing the operations of paragraphs 3.1.4 and 3.2.1, the bridge now balances with the following readings:

Capacitance = 138.25 pF
Conductance = 41.0 μmhos

From the equation of 3.2.5, the capacitance is:

$C_p = 138.25 - 120 + 0.53 = 18.78$ pF

where

C_{d_2} = 138.25 pF (final balance value)
C_{d_1} = 120 pF (from Table I)
C_c = +0.53 (from Figure 3-2)

From the equation of 3.2.6, the conductance is:

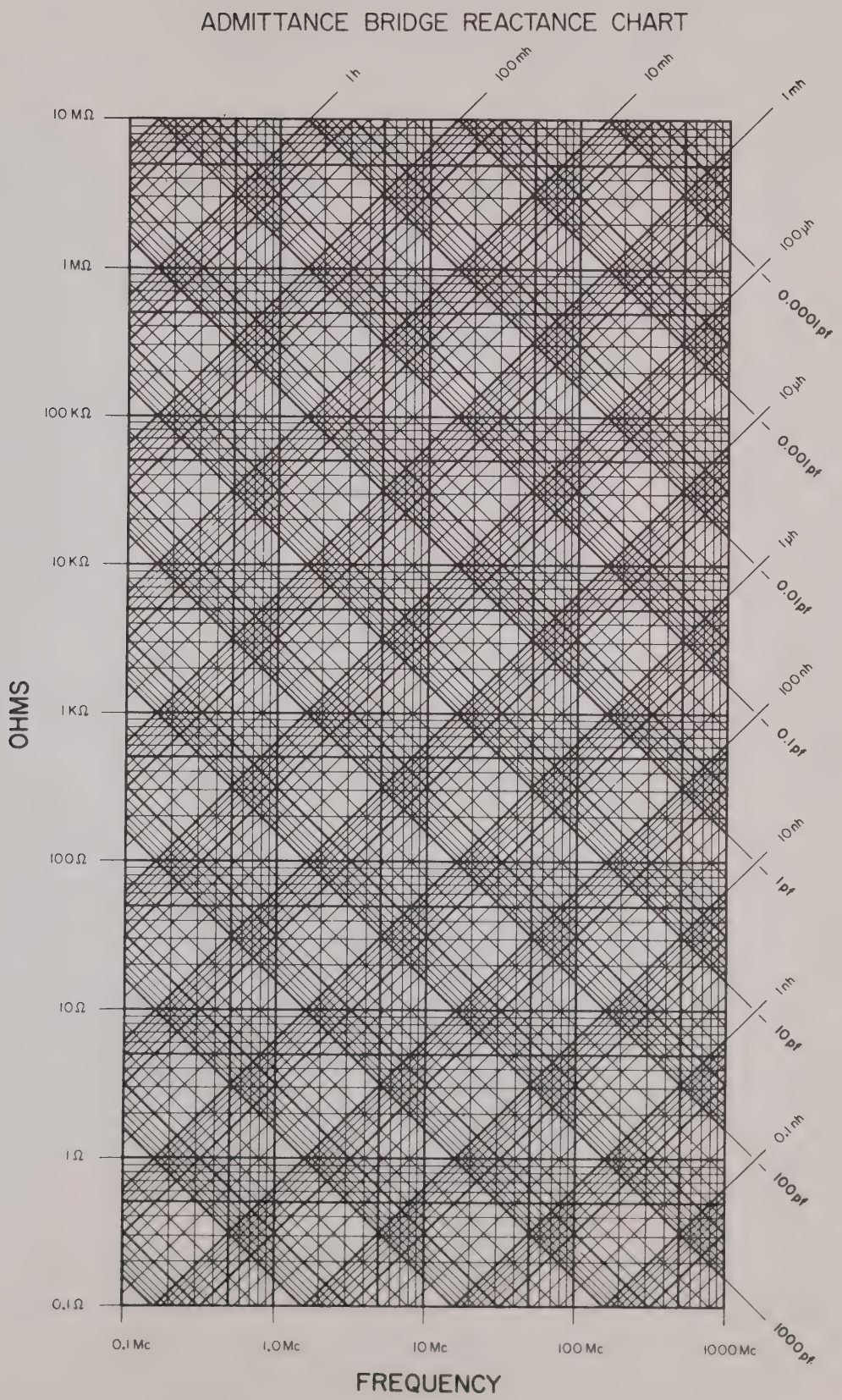
$G_p^* = 41.0 + (-2.3) = 38.7$ μmhos

where

G_c = (-5.6% of 41.0) = -2.3 μmhos (from Figure 3-3)

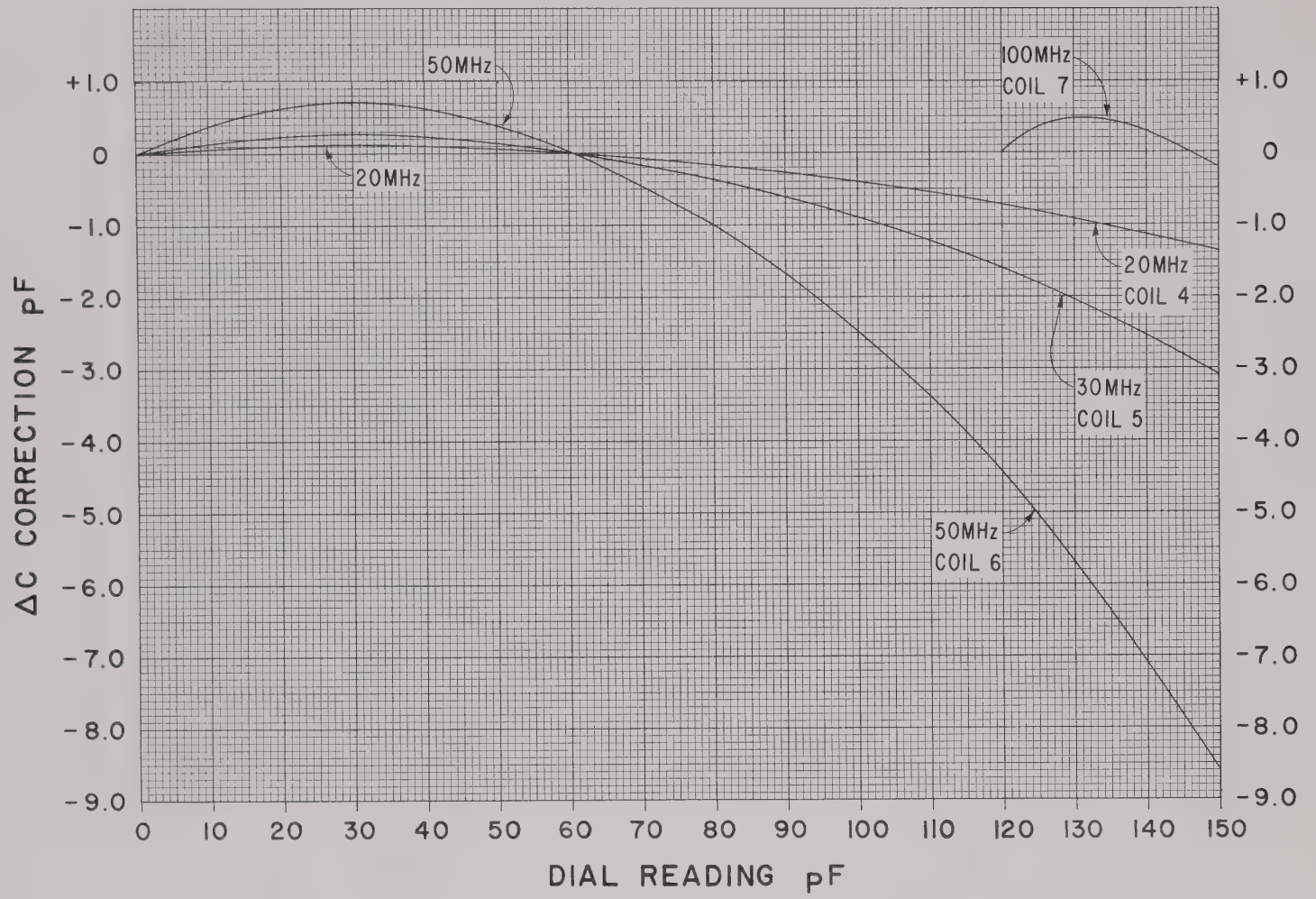
*NOTE: For the high Q case, an additional correction as established by the Model 33-8A Zero Conductance Standard may be applied to the measured conductance to provide better than specified accuracy. See page 5B-2.

Figure 3-1


ADMITTANCE BRIDGE REACTANCE CHART
1h
100mh
10mh
1mh
100µh
10µh
1µh
100nh
10nh
1nh
0.1nh
10 MΩ
1 MΩ
100 KΩ
10 KΩ
1 KΩ
100Ω
10Ω
1Ω
0.1Ω
OHMS
0.0001pf
0.001pf
0.01pf
0.1pf
1pf
10pf
100pf
1000pf
0.1 Mc
1.0 Mc
10 Mc
100 Mc
1000 Mc
FREQUENCY

MODEL 33A/1 OR 33B/1 RF ADMITTANCE BRIDGE

CAPACITANCE CORRECTION CURVES



TO CALCULATE THE CORRECTION AT OTHER FREQUENCIES

$$\Delta C_{f_x} = (f_x/f)^2 \Delta C_f$$

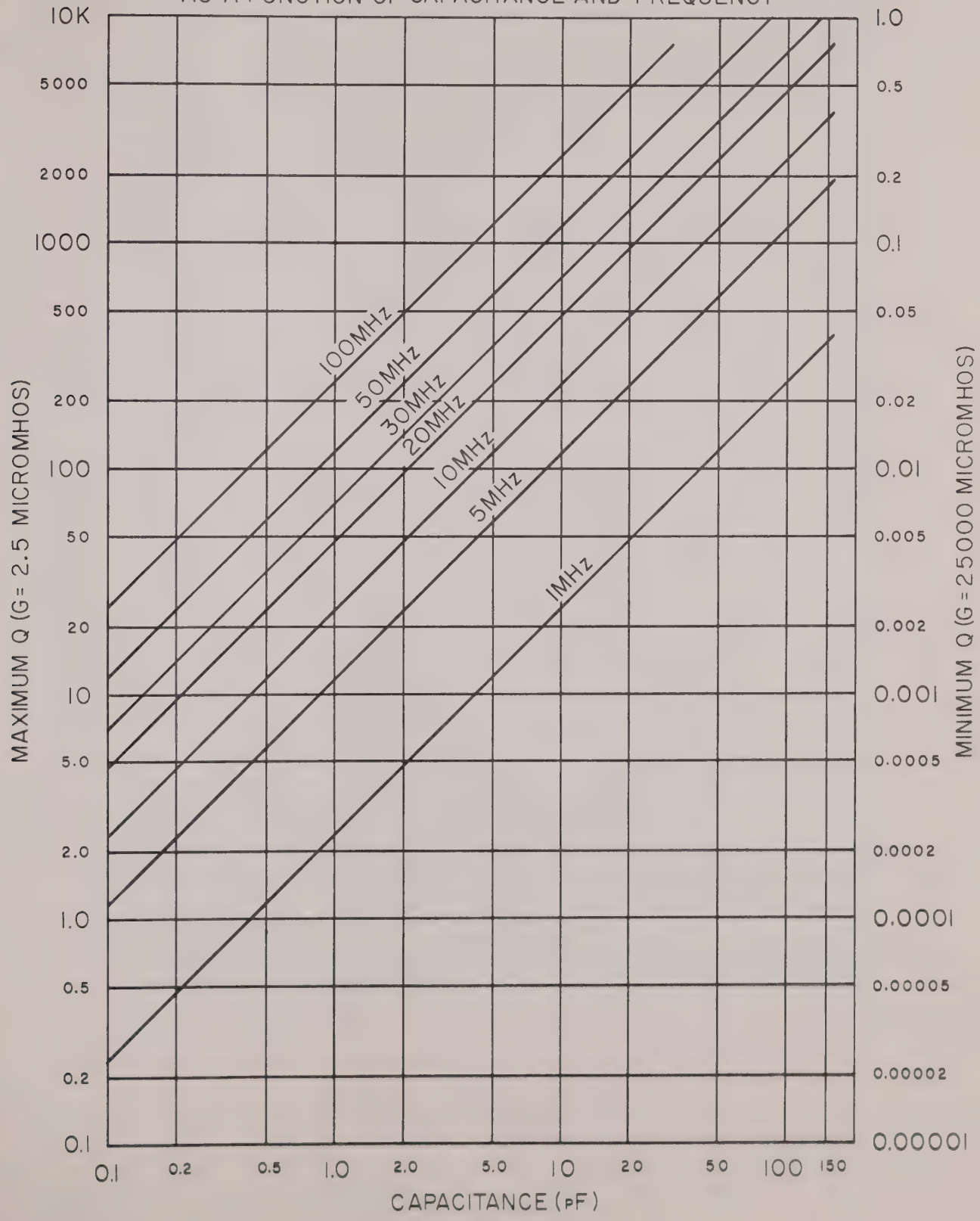
WHERE f_x = SPECIAL FREQUENCY
f = STANDARD FREQUENCY CLOSEST TO (f_x)

Figure 3-2

MODEL 33A RF ADMITTANCE BRIDGE

MAXIMUM/MINIMUM MEASURABLE Q

AS A FUNCTION OF CAPACITANCE AND FREQUENCY



MODEL 33A RF ADMITTANCE BRIDGE

CONDUCTANCE CORRECTION CURVES

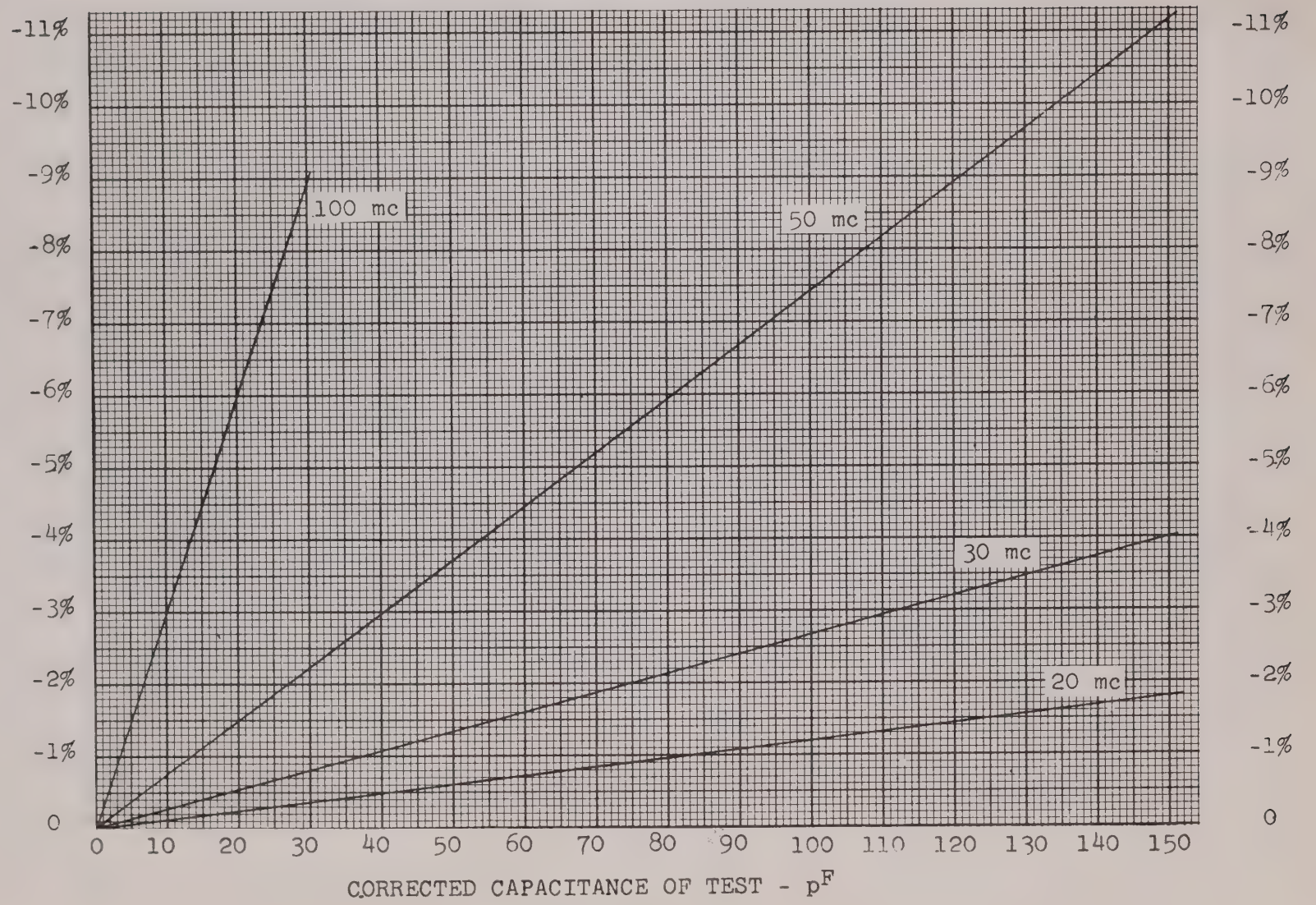
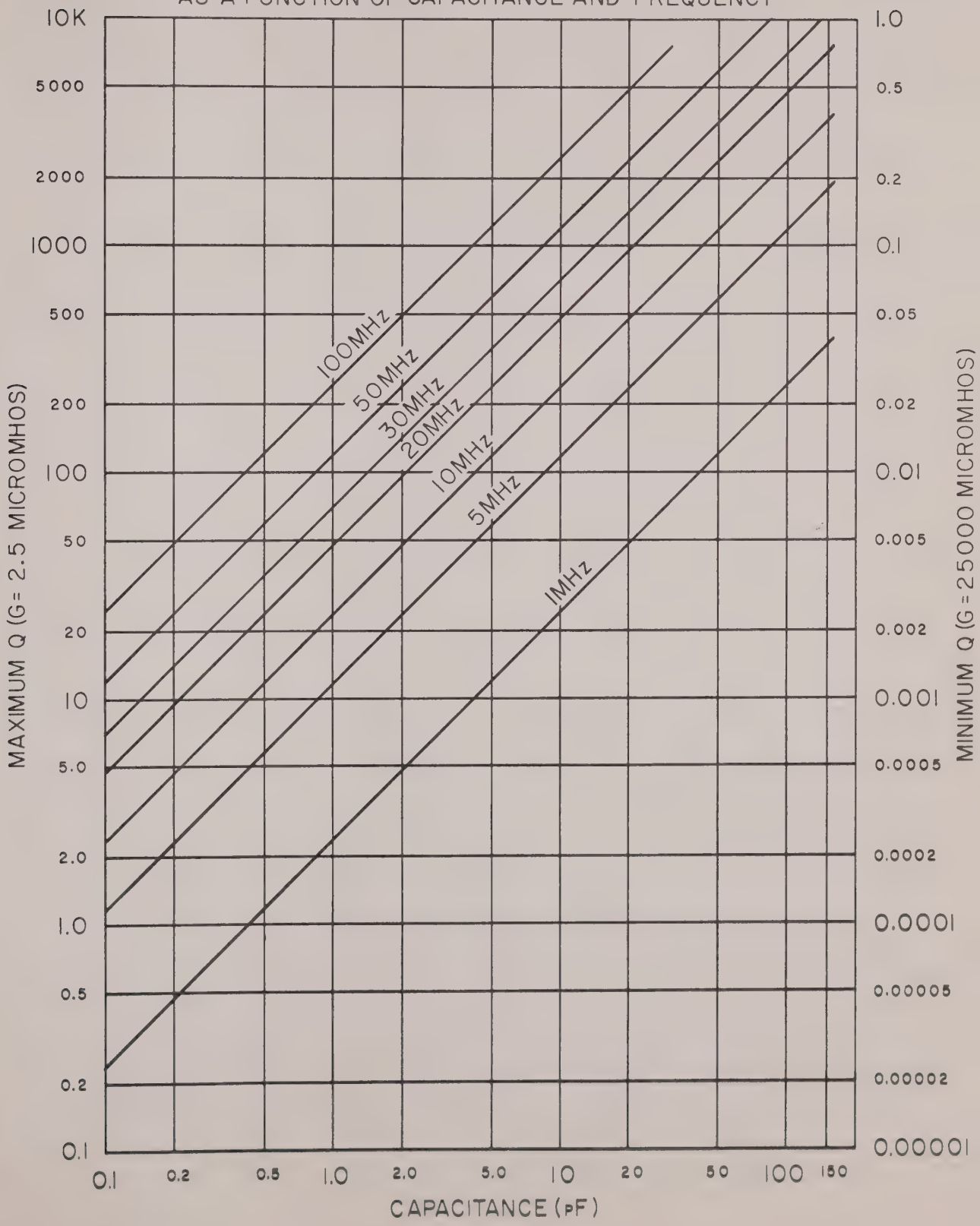


Figure 3-3

MODEL 33A RF ADMITTANCE BRIDGE

MAXIMUM/MINIMUM MEASURABLE Q

AS A FUNCTION OF CAPACITANCE AND FREQUENCY



SECTION IV

APPLICATIONS

33A/33B
(a)

DIELECTRIC
MEASUREMENTS

BOONTON ELECTRONICS CORPORATION

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33-1A DIELECTRIC SAMPLE HOLDER

The 33-1A Dielectric Sample Holder is designed to be used with the Model 33A RF Admittance Bridge or with the 75-4A Test Platform. It consists of a pair of solid silver capacitor plates with precision ground surfaces. Extreme care must be taken not to handle or damage these surfaces since the accuracy of the measurement is dependent upon their cleanliness and smoothness. Accuracy is also dependent upon the surface condition of the sample under test. The greater the intimacy of contact, the more accurate the results. Coating the sample with a thin layer of vaseline is an accepted method for improving this intimacy of contact, but the excess appearing at the outer edges and within the center hole must be wiped clean before the measurement.

For greater intimacy of contact, a metal film may be deposited on the surfaces of the sample. Recommended for this purpose is DuPont's Silver Preparation, Electronic Grade 4817. Spraying is preferred, but brushing is acceptable. Care must be taken to prevent the metallic film from coating the outer or inner edges of the sample. Whenever possible, coat the dielectric material first, then cut to size (especially when working with thin films). To prevent connection errors, the 33A top plate and the external surfaces of the sample holder must be clean.

The test sample must be the shape of a flat washer with the following dimensions:

Inside diameter	-	0.437 $\pm$.001 inches
Outside diameter	-	1.000 $\pm$.001 inches
Maximum thickness	-	0.130 inches

The accurate measurement of sample dimensions is essential to a proper result. The percentage error in the thickness measurement is reflected directly in the resultant dielectric constant, but a 0.1 percent error in the O.D. or I.D. measurement will appear as a 0.2 percent error in the measured K. As the sample becomes very thin, a potentially large percentage error in the thickness measurement can be held to a minimum by employing good equipment and techniques, and averaging out a number of measurements.

The method of measuring the dielectric constant is based on the standard relationship for the capacitance of a parallel plate capacitor.

$$C = 0.2244K \frac{A}{d} \text{ pF}$$

where

K = dielectric constant of the dielectric between the plates.

A = area of one plate, sq. in.

d = spacing of the plates, in.

Solving for K:

$$K = \frac{Cd}{0.2244A}$$

Since A is fixed by the specified sample and holder dimensions, the expression becomes:

$$K = \frac{Cd}{0.1426}$$

The dissipation factor is defined by the following relationship:

$$D = \frac{G}{\omega C}$$

where

G = conductance (loss) of dielectric, mhos

$\omega = 2\pi$ x test frequency

C = capacitance of dielectric, farads.

To use the Dielectric Sample Holder in conjunction with the 33A RF Admittance Bridge, proceed as follows:

1. Referring to Section III Page 3-1 and 3-2 of this Instruction Manual, remove both knurled nuts from the test terminals and follow the Operating Procedure for the initial setup of the bridge.

2. Place the dielectric sample between the two halves of the Dielectric Sample Holder and place assembly over the HI post. Add a knurled nut to clamp the assembly together and, at the same time, see that the sample is centered in the holder. Do not add knurled nut to GND post.

3. Make a measurement of capacitance and conductance.

4. The dielectric constant (K) for the sample is:

$$K = \frac{[(C_{d_2} - C_{d_1} + C_c) - C_f]\, d}{0.1426}$$

where

C_{d_1} = initial setting of CAPACITANCE dial.

C_{d_2} = final setting of CAPACITANCE dial with the sample in place.

C_c = correction applied to C_{d_2}. Refer to Figure 4A-1 for the correction at 20 Mc and above.

C_f = (Fringe capacitance) correction applied to C_{d_2} which is determined by the thickness of the sample under test. See Figure 4A-2.

d = thickness of sample in inches.

5. The dissipation factor (D) of the sample is:

$$D = \frac{G_p}{\omega[(C_{d_2} - C_{d_1} + C_c) - C_f]}$$

where

G_p = corrected conductance reading per Model 33-8A Zero Conductance Standard. See Page 5B-2.

ω = 2π x test frequency

75-4A TEST PLATFORM

The 75-4A Test Platform provides a convenient means of connecting the 33-1A Dielectric Sample Holder to any of our Series 74, 75, or 77 Capacitance Bridges.

To use the Sample Holder in conjunction with the Test Platform, proceed as follows:

1. Connect the Test Platform to the TEST BNC terminals and remove the thumbscrew from the test post.

2. Refer to the Capacitance Bridge Instruction Manual. With the bridge in the DIRECT mode, follow the Setup and Zero Balancing procedure.

3. Place the dielectric sample between the two halves of the Sample Holder and place assembly over test post. Add thumbscrew to clamp assembly together and, at the same time, see that sample is centered in holder.

4. Make a measurement of capacitance and conductance.

5. The dielectric constant (K) of the sample is:

$$K = \frac{(C_d + C_c - C_f)\ d}{0.1426}$$

where

C_d = corrected capacitance per Capacitance Bridge Instruction Manual (for test connected directly to the binding posts).

C_c = correction applied to value of capacitance obtained in step 4. See Figure 4A-3.

C_f = (Fringe Capacitance) correction applied to C_d (determined by the thickness of the sample under test). See Figure 4A-4.

6. The dissipation factor (D) of the sample is:

$$D = \frac{G_p + G_c}{\omega(C_d + C_c - C_f)}$$

where

G_p = corrected conductance reading per Capacitance Bridge Instruction Manual (for test connected directly to the binding posts).

G_c = correction applied to value of conductance obtained in Step 4. See Figure 4A-3.

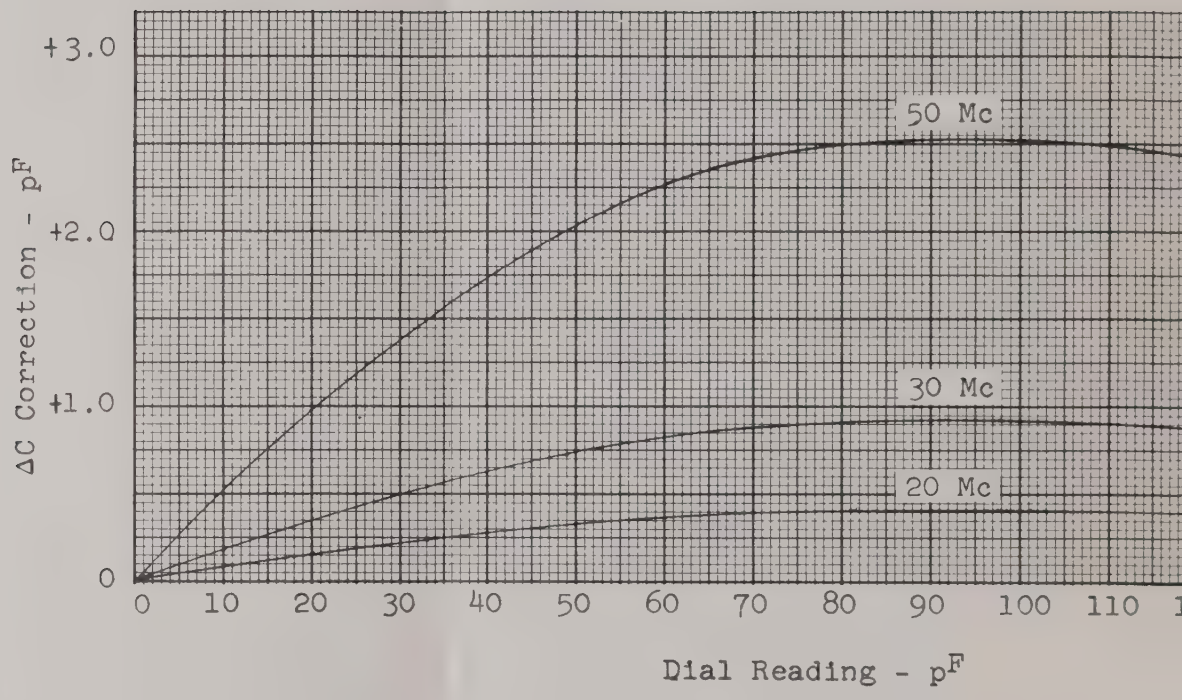
ω = 2π x test frequency.

MODEL 33A

CAPACITANC

TO BE USE

SAMPLE



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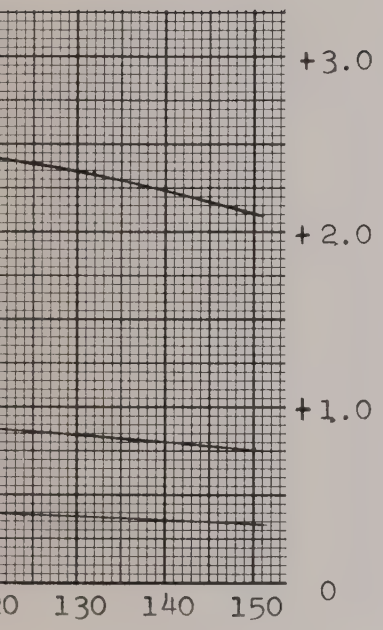
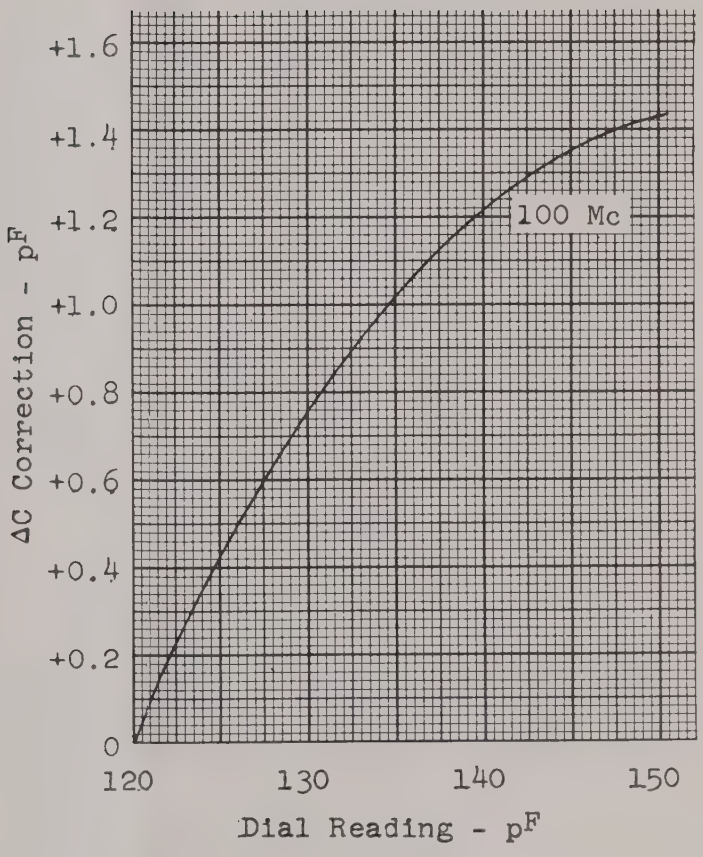
RF ADMITTANCE BRIDGE
E CORRECTION CURVES
D WITH DIELECTRIC
HOLDER 33-1A





33-1A
(a)

FRINGE CAPACITANCE CORRECTION CURVE

TO BE APPLIED WHEN 33-1A DIELECTRIC SAMPLE HOLDER
IS USED WITH 33A RF ADMITTANCE BRIDGE

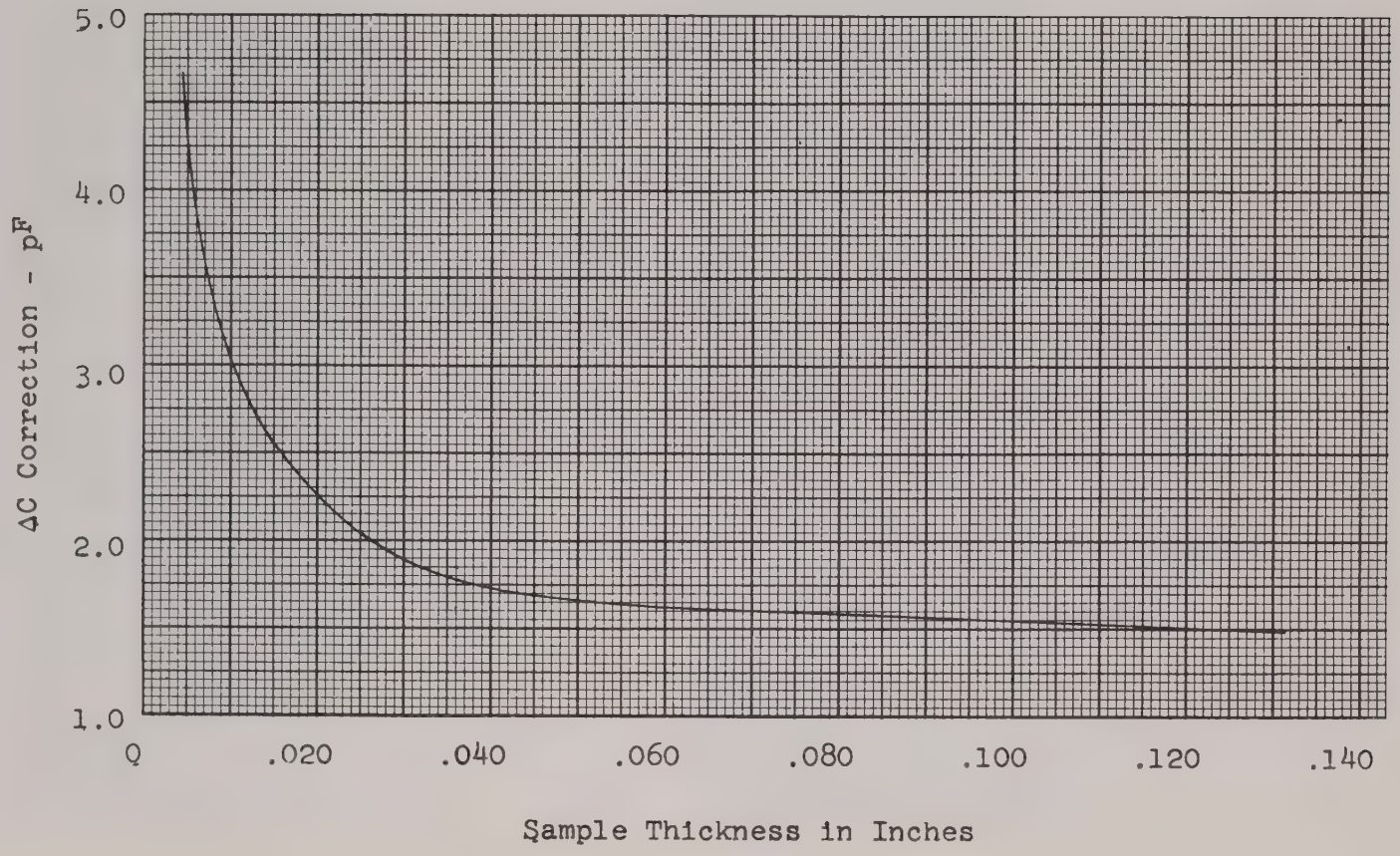


Figure 4A-2

1MC CAPACITANCE - CONDUCTANCE CORRECTION CURVES

TO BE USED WITH 75-4A TEST PLATFORM

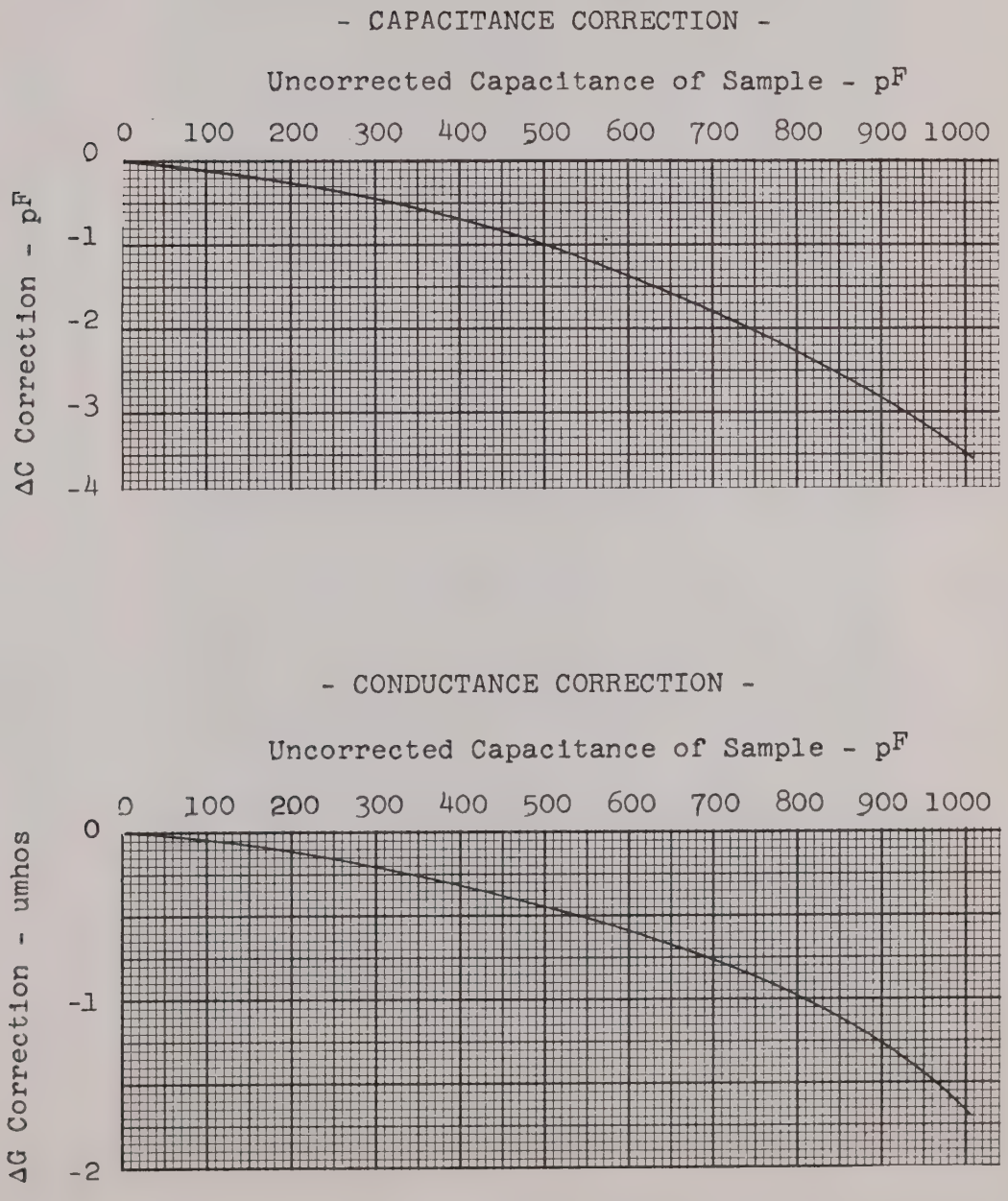


Figure 4A-3

FRINGE CAPACITANCE CORRECTION CURVE

TO BE APPLIED WHEN 33-1A DIELECTRIC SAMPLE HOLDER

IS USED WITH THE 75-4A TEST PLATFORM

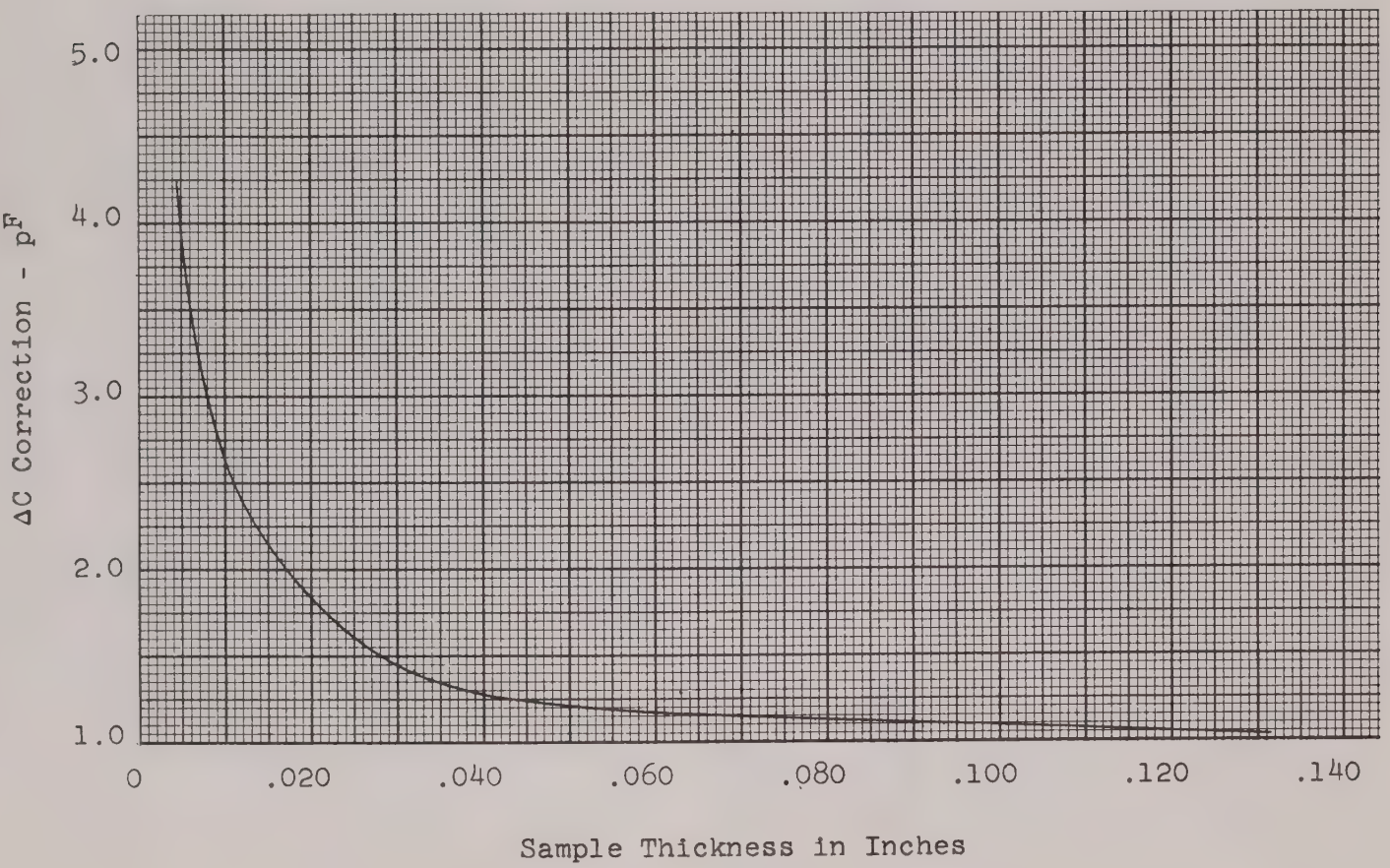
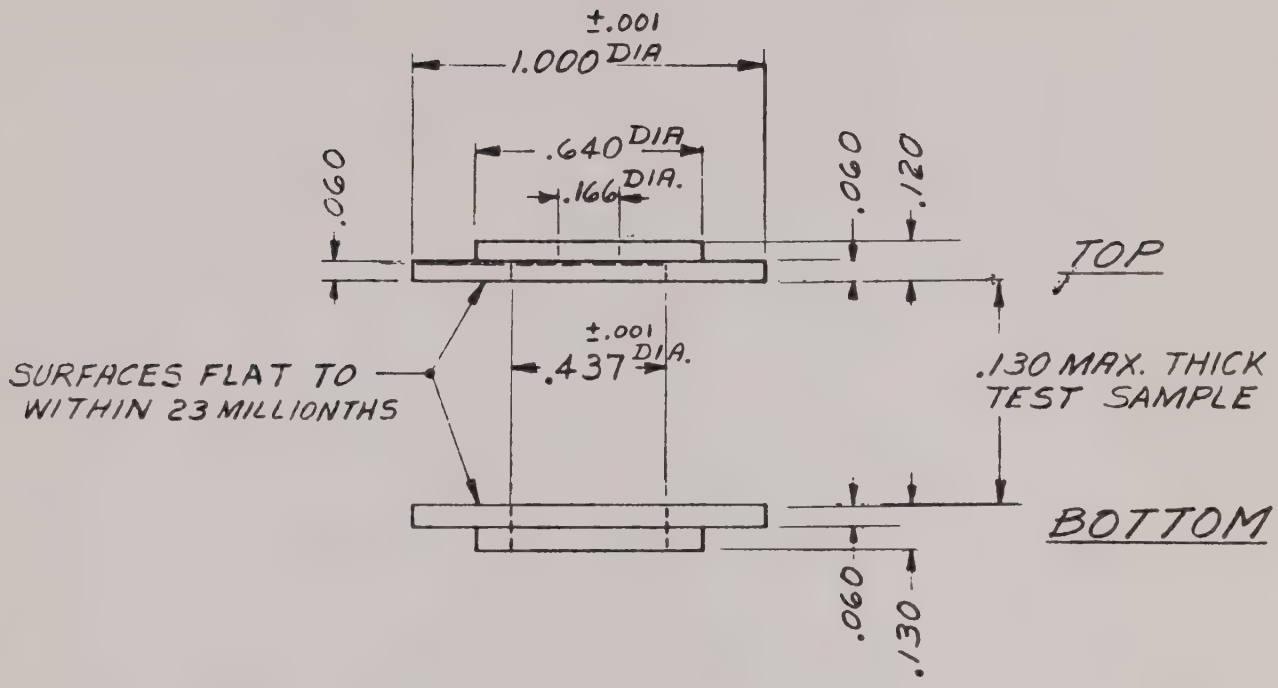


Figure 4A-4



MAT'L: COIN SILVER 4 No's. HARD

NOTE: PRECISION GROUND SURFACES TO HAVE BRIGHT SILVER FINISH. TARNISHED SURFACE NOT ACCEPTABLE.

Figure 4A-5
MODEL 33-1A DIELECTRIC SAMPLE HOLDER

Diode Measurements

33A
(a)

BOONTON ELECTRONICS CORPORATION

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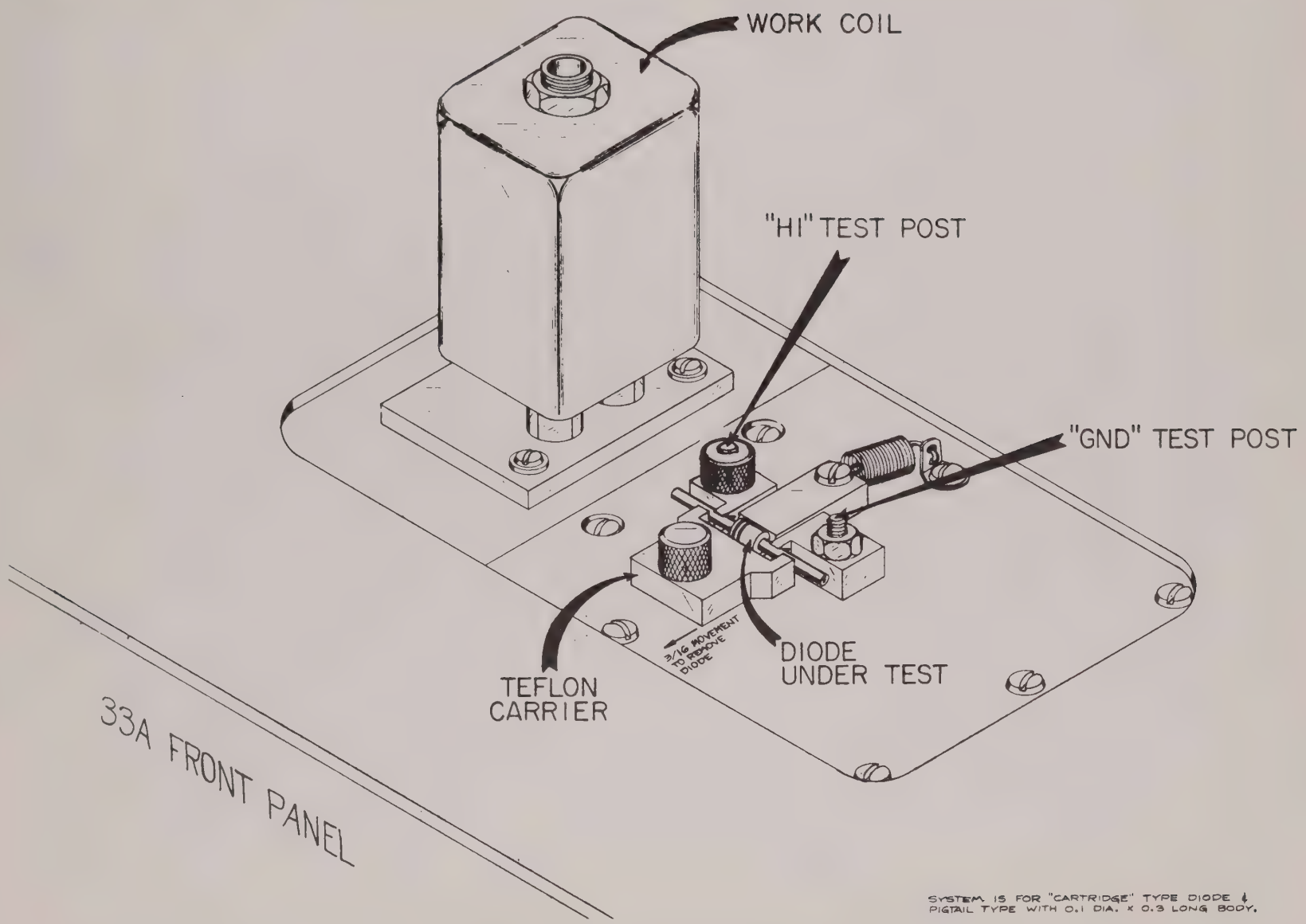
Model 33-2A Diode Test Fixture

Refer to Drawing No. C835010B for the general mounting of the Diode Test Fixture. Care must be taken in locating the contact blocks so that they are square and correctly spaced for free movement of the carrier without excessive side play. Place the counter bored "V" block on the left-hand (HI) terminal. Secure with thumbscrew only. Place the other "V" block on the right-hand (GND) terminal. Secure with the 8-32 nut removed from the terminal. The thumbscrew may also be placed above the nut in order that it may be kept with the instrument. Install the ground lug supplied as shown in the drawing and adjust for adequate spring tension.

When measuring diode characteristics, care must be taken to assure that the diode lead connected to the left hand (HI) binding post does not make electrical contact to any other part of the instrument. The appropriate Work Coil mounting post should be insulated with adhesive backed tape to help in this respect. The diode lead connected to the right-hand (GND) binding post may contact the top plate since this binding post is an integral part of the top plate.

To establish the exact capacitance of a diode, the distributed capacitance to ground of the lead extending from the HI post must be subtracted from the reading. Measure a diode with this lead in what will be its normal orientation. Then cut the lead to approximately 1/8" and again measure the diode capacitance. The difference between the two readings represents the capacitance contributed by the lead. Clean contacts are imperative for accurate results, therefore, frequent cleaning is recommended.

Figure 4B-1


WORK COIL
"HI" TEST POST
"GND" TEST POST
3/16 MOVEMENT TO REMOVE DIODE
DIODE UNDER TEST
TEFLON CARRIER
33A FRONT PANEL
SYSTEM IS FOR "CARTRIDGE" TYPE DIODE ↓ PIGTAIL TYPE WITH 0.1 DIA. x 0.3 LONG BODY.

MODEL 33-2A DIODE TEST FIXTURE

MODEL 33A RF ADMITTANCE BRIDGE

REMOTE MEASUREMENTS

USING

MODEL 33-3A COAX ADAPTER

AND

A HALF WAVELENGTH 50Ω TRANSMISSION LINE

BOONTON ELECTRONICS CORPORATION

Telephone: 201-887-5110 ■ TWX: 510-235-6747 ■ Route 287, Parsippany, N. J. – 07054

MODEL 33-3A COAX ADAPTER

Connector: Type "N" female
Characteristic Impedance: 50 ohms
Finish: Silver plate with gold flash

To install the Coax Adapter on the Model 33A RF Admittance Bridge, proceed as follows:

1. Remove the thumbscrew and nut from the GND binding post.
2. Using the Coax Adapter Plate as a guide, remove only the three 6-32 binding head screws from the 33A top plate which are required for mounting the Plate. (The 33A top plate must be clean.)
3. Place the Coax Adapter Plate over the HI and GND posts and loosely install the 3/8" 6-32 screws (supplied with the kit) and the GND post nut.
4. Remove the thumbscrew from the HI post and install the Coax Adapter Center Conductor (finger tight).
5. Rotate the Coax Adapter Barrel one or two turns into the Plate (not all the way through).
6. Carefully position the Plate so that the Center Conductor is centered in the Barrel, then tighten the three screws and the nut.
7. Rotate the Barrel until it seats (finger tight).

Measurements may now be made using standard transmission line techniques. Refer to following discussion for Theory and Measurement Technique.

REMOTE MEASUREMENT USING HALF WAVE LENGTH TRANSMISSION LINE

Theory

Environmental testing at radio frequencies usually requires physical separation of the measuring instrument and the device under test. Under certain conditions, a transmission line will behave as a one-to-one transformer, and if properly interposed, it can effect the necessary coupling and permit a direct measurement of the test specimen. The principle conditions under which the transmission line must operate are: 1) An adjustment of the length (or test frequency) for a half wavelength, or even multiple thereof, and 2) that the attenuation be small, so that,

$$(Y_o)\ \alpha\ell \ll Y_x$$

NOTE: See Index of Symbols, page 4C-10 for definition of these and subsequent symbols.

If these requirements are satisfied, remote measurements are only somewhat less convenient than direct measurements.

Generally, conventional co-axial transmission lines can be used successfully if only the major component of an admittance need be determined and the magnitude of this component is in the neighborhood of the iterative admittance of the line $(1/Z_o)$.

Difficulty with remote measurements over a half wavelength line arises when instrumentation is employed to measure both components of an unknown admittance in which the major component is susceptive and the Q is high. The problem with this condition is that the transmission line itself, in spite of a low attenuation factor, presents a conductive component at the input (measuring) terminals of the line which may approach, equal, or exceed the conductance of the device being tested. It will be shown that the attenuation of the line, which is a manifestation of the distributed series resistance and shunt conductance, influences the transmitted test conductance in such a way as to prohibit the simple subtraction of the line conductance from the total measured conductance. An expression is derived, however, which permits the calculation of the loss of a test specimen at the remote end of a half-wave line having more than negligible attenuation. It will also be shown that the susceptance of the test specimen is sensibly unmodified by the line.

The input impedance of a transmission line with a characteristic impedance, Z_o, terminated in an impedance, Z_L, is shown in many texts-1,2,3 as:

$$Z_{in} = Z_o \frac{Z_o \sinh \gamma\ell + Z_L \cosh \gamma\ell}{Z_o \cosh \gamma\ell + Z_L \sinh \gamma\ell} \tag{1}$$

which can be written,

$$Z_{in} = Z_o \frac{Z_L + Z_o \tanh \gamma\ell}{Z_o + Z_L \tanh \gamma\ell} \tag{2}$$

Where $\gamma = \alpha + j\beta$ = the propogation constant of the line.

It follows that,

$$Y_{in} = \frac{1}{Z_{in}} = \frac{1}{Z_o} \cdot \frac{Z_o + Z_L \tanh \gamma\ell}{Z_L + Z_o \tanh \gamma\ell} \tag{3}$$

Dividing numerator and denominator by $Z_o Z_L$

$$Y_{in} = Y_o \frac{Y_L + Y_o \tanh \gamma\ell}{Y_o + Y_L \tanh \gamma\ell} \tag{4}$$

but,

$$Y \tanh \gamma\ell = Y \frac{\sinh \alpha\ell \cdot \cosh \alpha\ell}{\sinh^2 \alpha\ell + \cos^2 \beta\ell} + jY \frac{\sin \beta\ell \cdot \cos \beta\ell}{\sinh^2 \alpha\ell + \cos^2 \beta\ell} \tag{5}$$

For electrically short lines, where $\alpha\ell < 0.1$ (this is well within the ratings of conventional coaxial lines), such that $\sinh \alpha\ell \approx \alpha\ell$, and with somewhat reduced accuracy, $\cosh \alpha\ell \approx 1.0$, we can write,

$$Y \tanh \gamma\ell \approx Y \left[\frac{\alpha\ell}{\alpha^2\ell^2 + \cos^2 \beta\ell} + j \frac{\sin \beta\ell \cdot \cos \beta\ell}{\alpha^2\ell^2 + \cos^2 \beta\ell} \right] \tag{6}$$

Thus,

$$Y_{in} = Y_o \frac{Y_L + Y_o\left[\frac{\alpha\ell}{\alpha^2\ell^2 + \cos^2\beta\ell} + j\,\frac{\sin\beta\ell \cdot \cos\beta\ell}{\alpha^2\ell^2 + \cos^2\beta}\right]}{Y_o + Y_L\left[\frac{\alpha\ell}{\alpha^2\ell^2 + \cos^2\beta\ell} + j\,\frac{\sin\beta\ell \cdot \cos\beta\ell}{\alpha^2\ell^2 + \cos^2\beta\ell}\right]} \quad (7)$$

If the line is very nearly a half wavelength, or even multiple thereof, then $\beta\ell \approx \pi$, and

$$\cos\beta\ell \approx 1.0$$

and $$\sin\beta\ell \approx 0$$

Thus,

$$Y_{in} = Y_o \frac{Y_L + Y_o\left[\frac{\alpha\ell}{\alpha^2\ell^2 + 1}\right]}{Y_o + Y_L\left[\frac{\alpha\ell}{\alpha^2\ell^2 + 1}\right]} \quad (8)$$

Having limited $\alpha\ell$ to 0.1, we may neglect $\alpha^2\ell^2$ compared to unity. At radio frequencies we can also assume the characteristic admittance of the line is sensibly real,

$$Y_o = G_o + j0$$

Eq. (8) then reduces to

$$Y_{in} = G_o \frac{Y_L + G_o\alpha\ell}{G_o + Y_L\alpha\ell} = \frac{G_o\,(G_L + G_o\alpha\ell + jB_L)}{G_o + G_L\alpha\ell + jB_L\alpha\ell} \quad (9)$$

Because this paper is concerned with a measurement made at the input of a half wavelength line (hereafter referred to as, the line), for an unknown terminating admittance Y_x, for convenience, let

$$Y_L = Y_x \quad (Y_x = \text{unknown value})$$

and $$Y_{in} = Y_m \quad (Y_m = \text{measured value via } \frac{\lambda}{2} \text{ line})$$

Also, $Y_x = G_x + jB_x$

and $Y_m = G_m + jB_m$

where $B_x = \omega C_x$ and $B_m = \omega C_m$

If the input admittance of the line is first measured for $Y_x = 0$ (open circuit condition),

then, from Eq (9)

$$Y_{in} = G_o \frac{Y_x + G_o \alpha \ell}{G_o + Y_x \alpha \ell}$$

$$Y_{in} = G_o \alpha \ell \tag{10a}$$

from which,

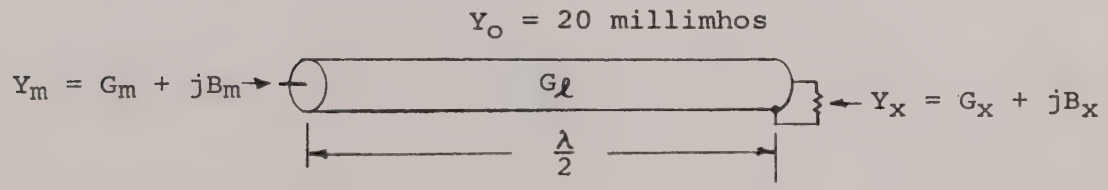
$$\alpha \ell = \frac{Y_{in}}{G_o} \tag{10b}$$

Let Y_{in} for this condition = G_ℓ (the open circuited conductance of the line owing to the attenuation constant).

Then,

$$\alpha \ell = \frac{G_\ell}{G_o} \tag{10c}$$

Eq. (9) may be solved for G_x and B_x and rearranged into conductance and susceptance components.



and,

$$G_x = \frac{G_o[G_oG_m - G_oG_\ell + \overbrace{\frac{G_mG_\ell^2}{G_o}}^{*} - (\frac{G_\ell}{G_o})(G_m^2 + B_m^2)]}{G_o^2 - 2G_mG_\ell + \underbrace{\frac{G_m^2G_\ell^2}{G_o^2} + \frac{B_m^2G_\ell^2}{G_o^2}}_{*}} \qquad (11)$$

* If $\frac{G_L}{G_o} = \alpha\ell \leq 0.1$, these terms are sensibly zero.

Thus,

$$G_x = \frac{G_m - G_\ell - (\frac{G_\ell}{G_o^2})(G_m^2 + B_m^2)}{1 - 2G_m(\frac{G_\ell}{G_o^2})} \qquad (12)$$

Let $Q_m = \frac{B_m}{G_m} = \frac{\omega C_m}{G_m}$

Then,

if $Q_m > 10$,

$$\boxed{G_x \approx G_m - G_\ell - (\frac{G_\ell}{G_o^2})(\omega C_m)^2} \qquad (13)$$

From Eq. (9) it can also be shown that,

$$B_x = \frac{G_o^2B_m(1 - \overbrace{\frac{G_\ell^2}{G_o^2}}^{*})}{G_o^2 - 2G_mG_\ell + \underbrace{\frac{B_m^2G_\ell^2}{G_o^2}}_{*}} \qquad (14)$$

* Neglect these terms if $\alpha\ell \leq 0.1$

or,

$$B_x = \frac{B_m}{1 - \frac{2G_mG_\ell}{{G_o}^2}} \approx B_m \tag{15}$$

Also,

$$\boxed{C_x = \frac{C_m}{1 - \frac{2G_mG_\ell}{{G_o}^2}} \approx C_m} \tag{16}$$

or,

$$L_x = L_m\left(1 - \frac{{G_o}^2}{2G_mG_\ell}\right) \approx L_m \tag{17}$$

In the exceptional case where $\frac{2G_mG_\ell}{{G_o}^2}$ cannot be neglected, we can eliminate it by taking the ratio of $\frac{B_x}{G_x}$.

Let $Q_x = \frac{B_x}{G_x}$

$$Q_x = \frac{B_m}{G_m - G_\ell - G_\ell \frac{{G_m}^2}{{G_o}^2}\,(1 + {Q_m}^2)} \tag{18}$$

$$Q_x = \frac{B_m}{G_m - G_\ell\left[1 + \frac{{G_m}^2}{{G_o}^2}\,(1 + {Q_m}^2)\right]} \tag{19}$$

where $Q_m = \frac{\omega C_m}{G_m}$

or $Q_m = \frac{1}{\omega L_m G_m}$

For the capacitive case,

If $Q_m \geq 10$

$$Q_x = \frac{\omega C_m}{G_m - G_\ell \left(1 + \frac{\omega_m C_m^2}{G_o^2}\right)} \qquad (20)$$

REFERENCES

1. Everett and Anner, "Communication Engineering", 3rd edition, p. 339, McGraw-Hill Book Co., 1956.

2. King, "Transmission Line Theory", p. 134, Dover Publications Inc., 1965.

3. Skilling, "Electric Transmission Lines", p. 88, McGraw-Hill Book Co., 1951.

INDEX OF SYMBOLS

Z_o = Characteristic impedance of the transmission line.

Z_{in} = Input impedance at sending end of the transmission line (measuring end).

Z_L = Load impedance at terminating end of the transmission line (test specimen).

$Y_L = \frac{1}{Z_L} = G_L + jB_L$

Y_o = Iterative, or characteristic admittance of the transmission line. $(Y_o = \frac{1}{Z_o})$

Y_m = Admittance measured at the input of the transmission line $(Y_m = G_m + jB_m)$.

$Y_{in} = Y_m$

Y_x = Unknown admittance of test specimen. $(Y_x = G_x + jB_x)$

α = Attenuation constant of the transmission line per unit length.

β = Phase constant of the transmission line per unit length.

γ = $\alpha + j\beta$ = propogation constant of the transmission line per unit length.

ℓ = Length of the transmission line (feet, meters, etc.).

λ = Wavelength at test frequency (feet, meters, etc.).

ω = $2\pi f$, where f = test frequency in hertz.

G_o = Conductive component of Y_o (at radio frequencies, $Y_o = G_o + j0$)

G_ℓ = Input conductance of half wavelength transmission line $(G_\ell = \alpha \ell G_o)$.

G_m = Measured conductance of test specimen as modified by the line.

G_x = Conductive component of the test specimen admittance.

B_m = Measured susceptance of the test specimen as modified by the line.

B_L = Susceptive component of the terminating admittance.

B_x = Susceptive component of the test specimen admittance.

Q_m = $\frac{B_m}{G_m}$ = measured Q of test specimen as modified by the line.

Q_x = $\frac{B_x}{G_x}$ = Q of test specimen.

C_m = Measured capacitance of test specimen as modified by the line (Farads).

C_x = Capacitance of test specimen (Farads).

L_m = Measured inductance of test specimen as modified by the line (Henries).

L_x = Inductance of test specimen (Henries).

Measurement Technique

The relatively straightforward derivation of the preceding equations must not be misconstrued to imply that the measurements can be made without special techniques, the utmost regard for lead length, and the proper adjustment of the half wave length line.

The use of long leads (particularly at the higher frequencies) to connect a test specimen to the bridge terminals, can result in appreciable error. For example, at 100 megacycles a 10 pF capacitor with 1/2 inch leads of #22 wire will measure 10% high. The relationship is easily derived and is known to be:

$$C = C_o/(1 - \omega^2 L C_o) = C_o/(1 - X_L/X_{C_o})$$

where

C_o is the true capacitance

L is the inductance of the leads

NOTE: The instrument calibration is based on the assumption that 1/8" leads will be required to connect the test specimen. The 1/2 inch leads referred to above are in addition to the 1/8 inch leads.

The same leads that cause an error at the terminals of the bridge will produce an even greater error when used at the remote end of a half wave length transmission line because they increase the measured susceptance thereby effecting a greater error in the transmitted conductance as shown in equation 13.

The recommended technique is as follows:

1. Install the Model 33-3A Coax Adapter Kit at the test terminals of the instrument. See Page 4C-2.
2. Select the Work Coil and Frequency of interest.
3. To establish the reactive reference, terminate the coax adapter with a low V.S.W.R. 50 ohm termination. (i.e., BEC 91-15A) Set the Capacitance dial as indicated on Work Coil. Balance the bridge for a null using the C-ZERO control and the CONDUCTANCE DIAL.
4. To establish the resistive reference, remove the 50 ohm termination, set the CONDUCTANCE DIAL to zero, and rebalance the bridge using the CAPACITANCE DIAL and the G-ZERO control.

   Steps 3 and 4 have established the proper settings for the zero controls so that the length of the half wavelength line and its loss may be measured.

5. To establish the $\lambda/2$ line and to measure its loss, add the line and all attachments up to the point of connection of the test specimen. Balance the bridge by adjusting the line length and the Conductance Dial. The reading on the Conductance Dial is G_ℓ

6. In order to read the quantity $(G_m - G_\ell)$ directly, return the Conductance Dial to zero and rebalance the bridge using the G-ZERO and C-ZERO controls.

7. To establish the distributed capacitance attributable to any attachments required to connect the test specimen, add those attachments, balance the bridge using the C and G dials, and note the readings. For best results, no change in Conductance should be introduced. This capacitance reading (C_T) should be noted as a zero reference.

8. Connect the test specimen and balance the bridge using the C and G dials. These readings are C_d and the quantity $(G_m - G_\ell)$ in the following computations.

9. Compute the true capacitance of the test specimen

$$C_x = C_d + C_c - C_T$$

where

C_x = True capacitance of test specimen

C_d = Final dial reading from Step 8

C_c = Correction applied to C_d
(See Fig. 3-2 Instruction Manual)

C_T = Distributed capacitance as determined in Step 7.

10. Compute the true conductance of the test specimen

$$G_X = (G_m - G_\ell) - G'$$

where

G_X = True conductance of test specimen

G_ℓ = Loss of the line as determined in Step 5

G_m = Measured conductance of the test specimen plus the line

$(G_m - G_\ell)$ = Conductance reading from Step 8.

$G' = \left[\frac{G_\ell}{G_o}2(\omega^2 C_m^2)\right]$ as determined by the nomograph. (Dwg. #C-830355-A)

$C_m = C_X + C_T$ (required for nomograph computation)

Example Measurement for 33A:

A capacitor of approximately 10 pF was to be measured at 100 Mc using a half wave length transmission line. The line selected was a GR 874-LTL adjustable trombone with a GR 874 ML component mount, two right angle connectors and a GR to Type N adapter. The component mount was modified so that the requirements of Step 5 could be met. All binding posts were removed and special 1/8" binding posts substituted which represented the point of contact of the test specimen.

Steps 1 thru 5 were performed, resulting in:

$$G_\ell = 147 \text{ μmhos}$$

Steps 6 and 7 were performed. This required the addition of the upper part of the special binding posts resulting in:

$$C_T = .42 \text{ pF}$$

Step 8 was performed resulting in the following readings:

$$C_d = 10.51 \text{ pF}$$

$$(G_m - G_\ell) = 125 \text{ μmhos}$$

Step 9 therefore gives a true capacitance of:

$$C_X = 10.51 + 0.62 - 0.42 = \underline{10.71 \text{ pF}}$$

where

C_d = 10.51 pF (dial reading)

C_c = 0.62 pF (from Fig. 3-2 Instruction Manual)

C_T = 0.42 pF (distributed capacitance in addition to test specimen capacitance)

and Step 10 gives a true conductance of:

$$G_X = (125) - 18 = \underline{107 \text{ μmhos}}$$

where

$(G_m - G_\ell)$ = 125 μmhos (reading from Step 8)

G' = 18 μmhos (calculated from nomograph)

Quantities required for nomograph computation:

G_{ℓ} = 147 μmhos (loss of line from Step 5)

C_m = 11.13 pF (C_X + C_T)

where

C_X = 10.71 pF

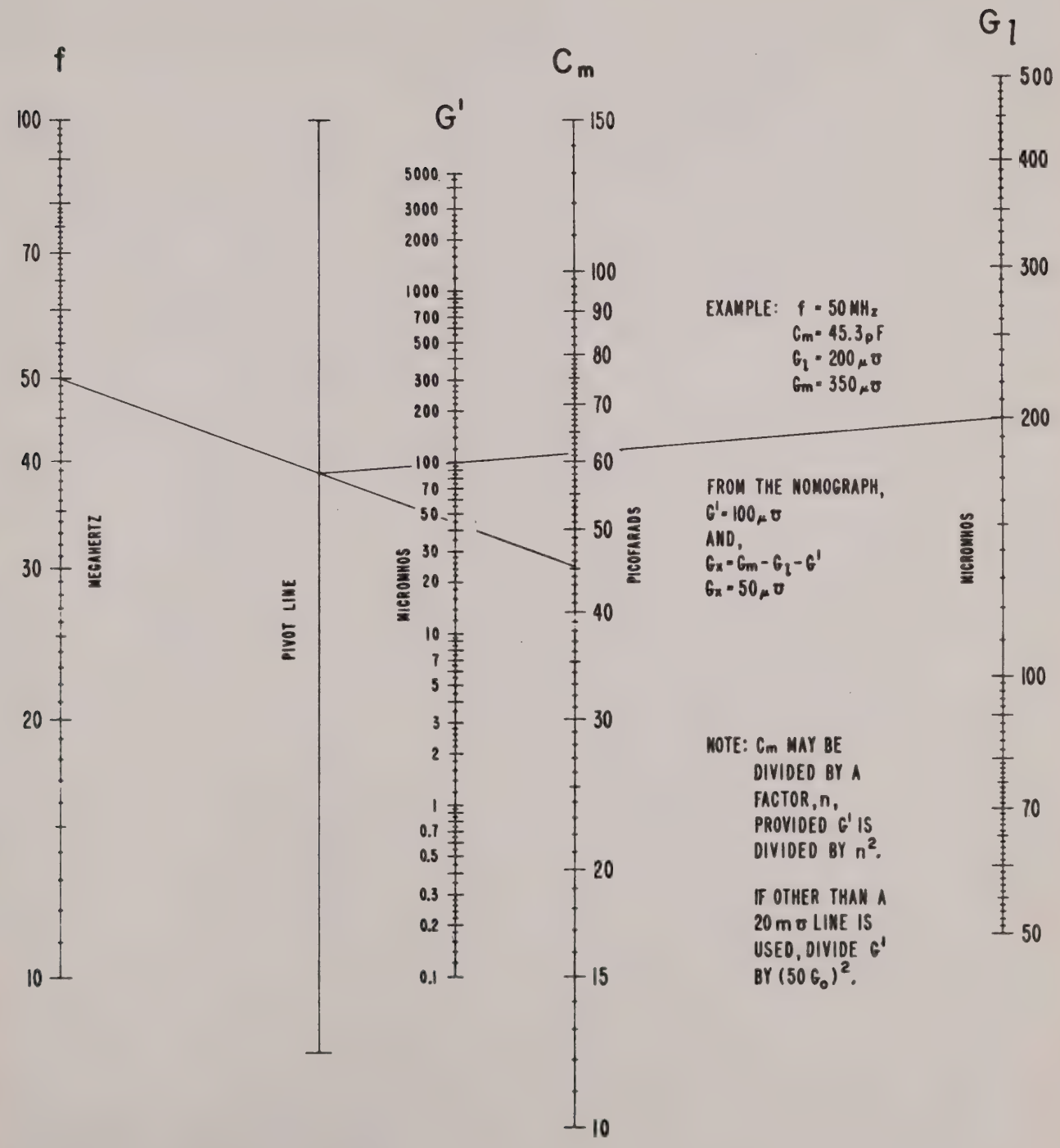
C_T = 0.42 pF

Correlation measurements made on unmodified 33A using same test specimen:

C_X = 10.38 pF $\qquad\qquad$ G_X = 104 μmhos

Figure 4C-1

NOMOGRAPH FOR LINE LOSS CORRECTION, G', OF A 20 mσ (50 Ω) HALF WAVELENGTH TRANSMISSION LINE USED FOR REMOTE MEASUREMENTS



Model 33A RF Admittance Bridge

Inductance Measurements

BOONTON ELECTRONICS CORPORATION

Telephone: 201-887-5110 ■ TWX: 510-235-6747 ■ Route 287, Parsippany, N. J. – 07054

Inductance Measurements Using Model 33-6A Work Coils

General

The Model 33-6A Work Coils are specifically designed to facilitate making inductance measurements with the Model 33A RF Admittance Bridge. Their function is to bring the bridge to balance at the high end of the capacitance scale, thus simplifying the measurement of inductance in terms of "negative" capacitance. Model 33-6A Coils are available for each of the seven test frequencies of the Model 33A, and their ranges of measurement are as follows:

Coil Number	Frequency	Measures from ∞ to approx:
1L	1 Mc/s	170 μH
2L	5 Mc/s	7 μH
3L	10 Mc/s	1.7 μH
4L	20 Mc/s	0.45 μH
5L	30 Mc/s	0.19 μH
6L	50 Mc/s	0.07 μH*
7L	100 Mc/s	0.017 μH*

*See note concerning measurement of small values of inductance on following page.

Initial Installation

Minor variations between individual Admittance Bridges require that each Inductance Work Coil be adjusted for the specific instrument with which it is to be used. To accomplish this initial adjustment, proceed as follows:

1. Turn Bridge on and allow at least 1/2 hour warm-up.
2. Insert the work coil in the three-terminal receptacle on top of the instrument and tighten the set screws to assure a stable, intimate contact.
3. Set the Frequency selector to the setting appropriate for the specific work coil.
4. Set main Conductance dial to zero.
5. Set main Capacitance dial to 150 pF.

6. Set C ZERO control to approximately the mid-point of its full traverse. This is most simply done by turning the control in one direction until it reaches the end-stop, then turning the control in the opposite direction for 5 1/2 turns.

7. By successive adjustment of the screw on top of the work coil and the G ZERO control, bring the bridge to balance.

8. Each of the "Inductance Work Coils" should be adjusted for the individual bridge, at the proper frequency following the procedure outlined above.

When the null is achieved, the coil is adjusted as required for that instrument.

NOTE: The coil need not be readjusted as long as it is used only with the instrument with which it was adjusted according to the above procedure. However, if it is to be used with another Model 33A, the adjustment procedure should be repeated before attempting inductance measurements.

Inductance Measuring Procedure

To measure inductance with the Model 33A, install the "L" work coil for the appropriate frequency, zero the bridge at 150 pF* and then proceed to make the measurement in the same manner as that for making capacitance measurements as outlined in the instruction book. The result, in pF, is submitted to the following computation to derive the inductance value.

$$L_p = \frac{1}{\omega^2 (C_{d1} - C_{d2})} = \text{parallel inductance}$$

Where C_{d1} = 150 pF (initial capacitance reading)

C_{d2} = final capacitance reading

$\omega^2 = (2\pi f)^2$

Q may be determined from $Q = \frac{(C_{d1} - C_{d2})\omega}{G_p}$ or $Q = \frac{1}{\omega L_p G_p}$

Where L = the calculated value and G the conductance reading.

*Balancing the bridge at 150 pF for inductance measurements is recommended only because it provides the greatest measuring range. In actual practice, the bridge may be zeroed with the Capacitance dial set to any logical value. However, in the determination of L, the capacitance value at which the bridge is zeroed prior to measurement should be entered instead of 150 pF in the above computation.

IMPORTANT NOTE: A small residual inductance of approximately 0.007 μH, attributable to the binding posts and bridge geometry, is in series with the unknown and must be subtracted from the resultant L, as calculated above. This inductance must be taken into consideration especially when making measurements of small inductance values.

SECTION V

Model 33A RF Admittance Bridge

Accessories

INDEX

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33-1A	Dielectric Sample Holder	4A-2
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33-9A	Capacitance Standards	5A-2
33-10A	Conductance Standards	5B-5

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Model 33A RF Admittance Bridge

Capacitance Standards

33A
(a)

CAPACITANCE CALIBRATION CHECK
FOR
MODEL 33A RF ADMITTANCE BRIDGE

The Model 33-9A Capacitance Standards have been designed for checking the calibration accuracy of the Boonton Electronics Model 33A RF Admittance Bridge. The electrical and mechanical parameters of the Model 33-9A standards have been carefully chosen so that the capacitance value is constant over the frequency range of the instrument.

To check the capacitance calibration of the Model 33A at any frequency, proceed as follows:

1. Zero the bridge with the appropriate work coil installed and the test post knurled nuts seated.

2. Connect each Capacitance Standard in turn and record the readings. The Standards must be connected so that the larger terminal lug containing the serial number is at the GND binding post. All contact surfaces must be clean.

3. Apply the appropriate correction to each reading using the correction curves of Figure 3-2.

4. Calculate the percentage error between the corrected readings and the value of each standard.

5. Compare this to the allowable percent error as specified by the accuracy statement in the Instruction Manual.

CALIBRATION CERTIFICATE
FOR
CAPACITANCE STANDARDS
MODEL 33-9A

Calibrated for use with Boonton Electronics Corporation
Model 33A RF Admittance Bridge

Serial Number	1 MHz Capacitance,* picofarads	Accuracy at 25°C

*Capacitance calibration is valid only when the Standard is properly connected (large tab to GND post) to the unmodified binding posts of a Model 33A R.F. Admittance Bridge.

Calibrated _____

Approved _____

Date _____

BOONTON ELECTRONICS CORPORATION

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Model 33A RF Admittance Bridge

Conductance Standards

ZERO CONDUCTANCE STANDARD

MODEL 33-8A

FOR

MODEL 33A RF ADMITTANCE BRIDGE

The Zero Conductance Standard (33-8A) is silver plated and gold flashed and, in conjunction with the top plate of the Model 33A RF Admittance Bridge, forms a sensibly lossless capacitor which is adjustable to about 50 pF. Small residual series losses within the bridge, which cannot be balanced out by the initial "zeroing", may contribute a large percentage error in high Q measurements as indicated by the conductance accuracy statement.

To establish the conductance correction attributable to these small internal losses at any frequency, proceed as follows:

1. To prevent the introduction of an unknown loss, clean any foreign matter from the following:
    a. HI and GND post threads and 33-8A threads.
    b. Contact surfaces of the thumbscrews.
    c. Contact surfaces of the test terminal nuts.
    d. Top plate surface.
2. Place the 33-8A-1 fixture on the HI post. Omit thumbscrew. Remove GND post thumbscrew.
3. Set the CAPACITANCE dial to reading on work coil.
4. Set the CONDUCTANCE dial to some up-scale reading. (5 μmhos typical)
5. Balance the bridge using the zero controls.

6. Rock the CAPACITANCE and CONDUCTANCE dials to assure that the bridge is exactly balanced at the selected readings.*

7. Remove the 33-8A-1 fixture and screw the 33-8A-2 fixture onto the HI post to a position which corresponds to the approximate value of the capacitance of interest. Add thumbscrew to lock in place.

8. Rebalance the bridge using the CAPACITANCE and CONDUCTANCE dials.*

9. The reading on the CONDUCTANCE dial will be in a negative direction from the original balance point by an amount equal to the required correction for the value of capacitance indicated on the CAPACITANCE dial. The reading may be in a positive direction for larger values of capacitance (40 to 50 pF) indicating that the internal losses are less than those associated with the "lossless" capacitor and therefore no correction is required.

10. Recheck the original "zero"* (5 μmhos) of the CONDUCTANCE dial with the 33-8A-2 removed and the 33-8A-1 installed. This must check out for accurate results. Avoid touching the Work Coil, stressing the HI post, or jarring the bridge after "zeroing" as an apparently insignificant movement here can displace the zero balance.

11. When measuring high Q components to better than specified accuracy, the correction, as established above, must be added to the corrected Conductance reading.

* See Note Page 5B-4

Zero Conductance Standard
Model 33-8A for
Model 33A RF Admittance Bridge

IMPORTANT: The utmost care must be exercised in (1) establishing the initial zero conditions, (2) balancing the capacitance and conductance to a complete null, and (3) ascertaining that the zero reference has not shifted during the measurement if the results are to be accurate and repeatable. The instrument must be used at full sensitivity and RF level. But at those frequencies where the Capacitance dial becomes extremely sensitive, the C-Zero control may be used for final balance as long as it is not rotated more than 90° from its "zero" position. It is recommended that the instrument be stabilized with the work coil in place for at least 4 hours before attempting the above procedure.

CONDUCTANCE CALIBRATION CHECK
FOR
MODEL 33A RF ADMITTANCE BRIDGE

The Model 33-10A Conductance Standards have been designed for checking the calibration accuracy of the Model 33A RF Admittance Bridge.

To check the conductance calibration of the Model 33A, proceed as follows:

1. Zero the bridge with the 1 Mc work coil installed.
2. Connect each conductance standard in turn and record the readings. All contact surfaces must be clean.
3. Calculate the percentage error between the dial reading and the value given on the calibration certificate.
4. Compare this to the allowable % error as specified in the instruction manual.

To check the conductance calibration with frequency:

1. Zero the bridge with each work coil installed.
2. Connect the 10,000 μmho standard and record the reading for this unit. (See Note 1)
3. Calculate the percentage error between the dial reading and the value given in the table.
4. Compare this to the allowable % error as specified in the instruction manual. (See Note 2)

Note 1 As the frequency increases, the 10,000 μmho standard is the only one which can be expected to give a correct reading. Because of their distributed capacitance and inductance, the others will read high or low, depending upon their value. In the 10,000 μmho unit, the net distributed reactance is sufficiently small, thus introducing a negligible error in the conductance reading at the higher frequencies.

Note 2 If the 10,000 μmho reading at the higher frequencies and the 1 Mc readings of part A are all within the specification, then the conductance dial is within specification for the entire frequency range.

CALIBRATION CERTIFICATE
FOR
CONDUCTANCE STANDARDS
MODEL 33-10A

Calibrated for use with Boonton Electronics Corporation
Model 33A RF Admittance Bridge

Serial Number	1 MHz Conductance,* micromhos	Accuracy at 25°C

*Conductance calibration is valid only when the Standard is properly connected (large tab to GND post) to the unmodified binding posts of a Model 33A RF Admittance Bridge.

Calibrated _____

Approved _____

Date _____

BOONTON ELECTRONICS CORPORATION

Telephone: 201-887-5110 ■ TWX: 510-235-6747 ■ Route 287, Parsippany, N. J. – 07054

SECTION VI

TABLE OF REPLACEABLE PARTS - 33A
(Serial Number 282 and Up)
Test Oscillator

	Reference	Description	BEC Part No.
C101	Capacitor	0.01 µF 400 WV	236,004
C102	"	0.047 µF 10% 400 V	236,002
C103	"	0.047 µF 10% 400 V	236,002
C104	"	0.01 µF 400 WV	236,004
C105	"	0.1 µF 400 V	236,001
C106	"	0.1 µF 400 V	236,001
C107	"	56 pF 500 WV	200,003
C108	"	680 pF 500 WV	200,015
C109	"	0.01 µF 100 WV	224,119
C110	"	100 pF 500 WV	200,001
L101	Choke, RF	2.5 mH	400,014
L102	"	2.5 mH	400,014
L103	"	47 µH	400,076
L104	"	55 µH	400,015
L105	"	55 µH	400,015
L106	"	6800 µH	400,074
L107	"	150 µH	400,081
L108	"	47 µH	400,076
L109	"	10 µH	400,077
L110	"	4.7 µH	400,079
L111	"	1.5 µH	400,078
L112	"	0.47 µH	400,080
R101	Resistor	10KΩ 5% 1/2W	301,111
R102	"	10KΩ 5% 1W	302,125
R103	"	10KΩ 5% 1/4W	300,106
R104	"	470Ω 5% 1/4W	300,074
R105	" Var.	250Ω 20% 2W	311,199
R106	"	47Ω 5% 1/4W	300,050
R107	"	100Ω 5% 1/4W	300,058
R108	" Factory selected value		
R109	"	470Ω 5% 1/4W	300,074
T101	Transformer Assembly	(1)	410,021
T102	"	(5)	410,023
T103	"	(10)	410,025
T104	"	(20)	410,027
T105	"	(30)	410,029
T106	"	(50)	410,031
T107	"	(100)	410,033
TR101	Trap Assembly	(TR)	400,097

Reference		Description	BEC Part No.
V101	Tube	6BK7A	5266BK7
Y101	Crystal	1000 Kc/s	547,008*
Y102	"	5000 Kc/s	547,009*
Y103	"	10,000 Kc/s	547,010*
Y104	"	20,000 Kc/s	547,011*
Y105	"	30,000 Kc/s	547,012*
Y106	"	50,000 Kc/s	547,013*
Y107	"	100,000 Kc/s	547,014*

*This number includes matched local oscillator crystal. Crystals must be replaced in pairs

Local Oscillator

C201	Capacitor	0.01 µF 400WV	236,004
C202	"	0.047 µF 10% 400V	236,002
C203	"	0.047 µF 10% 400V	236,002
C204	"	0.01 µF 400WV	236,004
C205	"	0.1 µF 400V	236,001
C206	"	0.1 µF 400V	236,001
C207	"	56 pF 500V	200,003
C208	"	680 pF 500WV	200,015
C209	"	0.01 µF 100WV	224,119
L201	Choke, RF	2.5 mH	400,014
L202	"	2.5 mH	400,014
L203	"	47 µH	400,076
L204	"	55 µH	400,015
L205	"	55 µH	400,015
L206	"	6800 µH	400,074
L207	"	150 µH	400,081
L208	"	47 µH	400,076
L209	"	10 µH	400,077
L210	"	4.7 µH	400,079
L211	"	1.5 µH	400,078
L212	"	0.47 µH	400,080
R201	Resistor	10KΩ 5% 1/2W	301,111
R202	"	10KΩ 5% 1W	302,125
R203	"	10KΩ 5% 1/4W	300,106
R204	"	470Ω 5% 1/4W	300,074
R205	"	Factory selected value	
R206	"	Factory selected value	
R207	"	470Ω 5% 1/4W	300,074

Reference		Description	BEC Part No.
T201	Transformer Assembly	(1)	410,022
T202	" "	(5)	410,024
T203	" "	(10)	410,026
T204	" "	(20)	410,028
T205	" "	(30)	410,030
T206	" "	(50)	410,032
T207	" "	(100)	410,034
V201	Tube	6BK7A	526,6BK7
Y201	Crystal	1465 Kc/s	547,008*
Y202	"	5465 Kc/s	547,009*
Y203	"	10,465 Kc/s	547,010*
Y204	"	20,465 Kc/s	547,011*
Y205	"	30,465 Kc/s	547,012*
Y206	"	50,465 Kc/s	547,013*
Y207	"	100,465 Kc/s	547,014*

*This number includes matched test oscillator crystal. Crystals must be replaced in pairs.

Bridge Section

Components in the "Bridge" section have not been included, since, in general, their replacement must be followed by adjustments that require specialized equipment and techniques.

C313	Capacitor	0.22 µF 200V	235,025
L302-1	Work Coil	1 Mc/s	033,021
L302-2	"	5 Mc/s	033,022
L302-3	"	10 Mc/s	033,023
L302-4	"	20 Mc/s	033,024
L302-5	"	30 Mc/s	033,025
L302-6	"	50 Mc/s	033,026
L302-8	"	100 Mc/s	033,028

Mixer Section

C401	Capacitor	0.01 µF 100V	224,119
C402	"	0.01 µF 100V	224,119
C407	" , Feedthru	7000 pF 20%	227,102
C408	"	24 pF 500V	200,009
C409	" , Trimmer	7 to 45 pF	275,114
C410	"	0.02 µF 500V	224,118
C411	" , Feedthru	7000 pF	227,102
C412	"	0.01 µF 100V	224,119

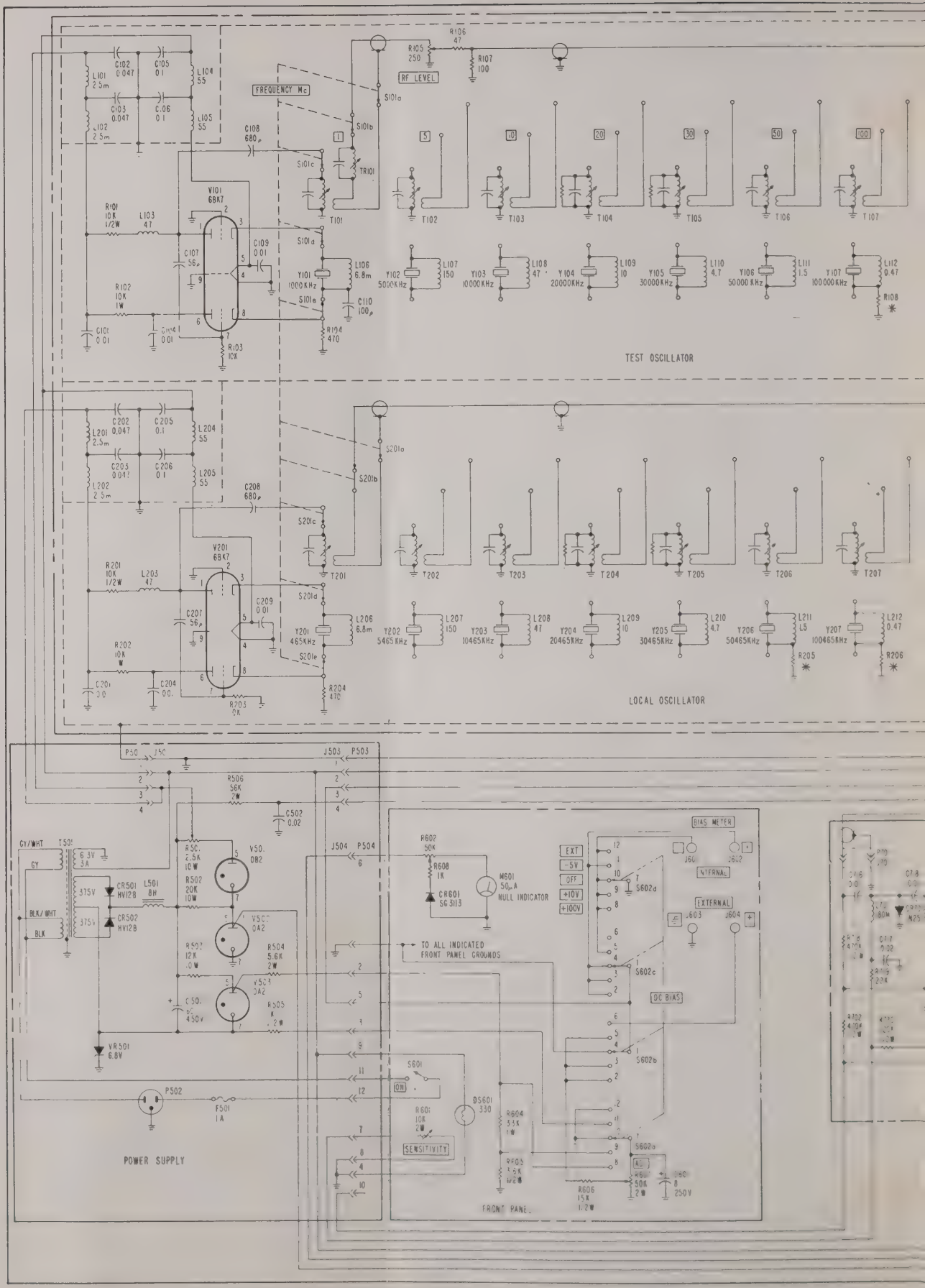
Reference		Description	BEC Part No.
CR401	Diode	1N58A	530,021
L402	Choke	1000 µH 5%	400,095
L403	"	5600 µH 5%	400,138
L404	"	2200 µH 5%	400,039
R409	Resistor	47Ω 5% 1/2W	301,055
R410	"	56Ω 5% 1/2W	301,057
R411	"	1MΩ 5% 1/2W	301,159
R412	"	470K 5% 1/2W	301,151
V401	Tube	6EW6	5266EW6
		Power Supply	
C501	Capacitor	20/20/20 µF 450V	283,113
CR501	Diode, Silicon	1200V P.I.V. 250mA	532,007
CR502	"	1200V P.I.V. 250mA	532,007
F501	Fuse	1 Amp (117V MODEL)	545,500
F501	"	1/2 Amp (234V MODEL)	545,502
L501	Choke		440,006
R501	Resistor, Adjustable	2.5KΩ 10W	312,114
R502	"	20KΩ 10W	310,003
R503	"	12KΩ 10W	310,002
R504	"	5.6KΩ 5% 2W	304,105
R505	"	1KΩ 5% 1/2W	301,087
R506	"	56K 5% 2W	304,129
T501	Transformer, Power		446,021
V501	Tube	OB2	526OB2
V502	"	OA2	526OA2
V503	"	OA2	526OA2
VR501	Diode, Zener	6.8V	530,067
		Front Panel	
C601	Capacitor	8 µV 250V	283,148
CR601	Diode, Silicon	SG 3113	530,040
DS601	Bulb	#330 14V 80mA	545,110

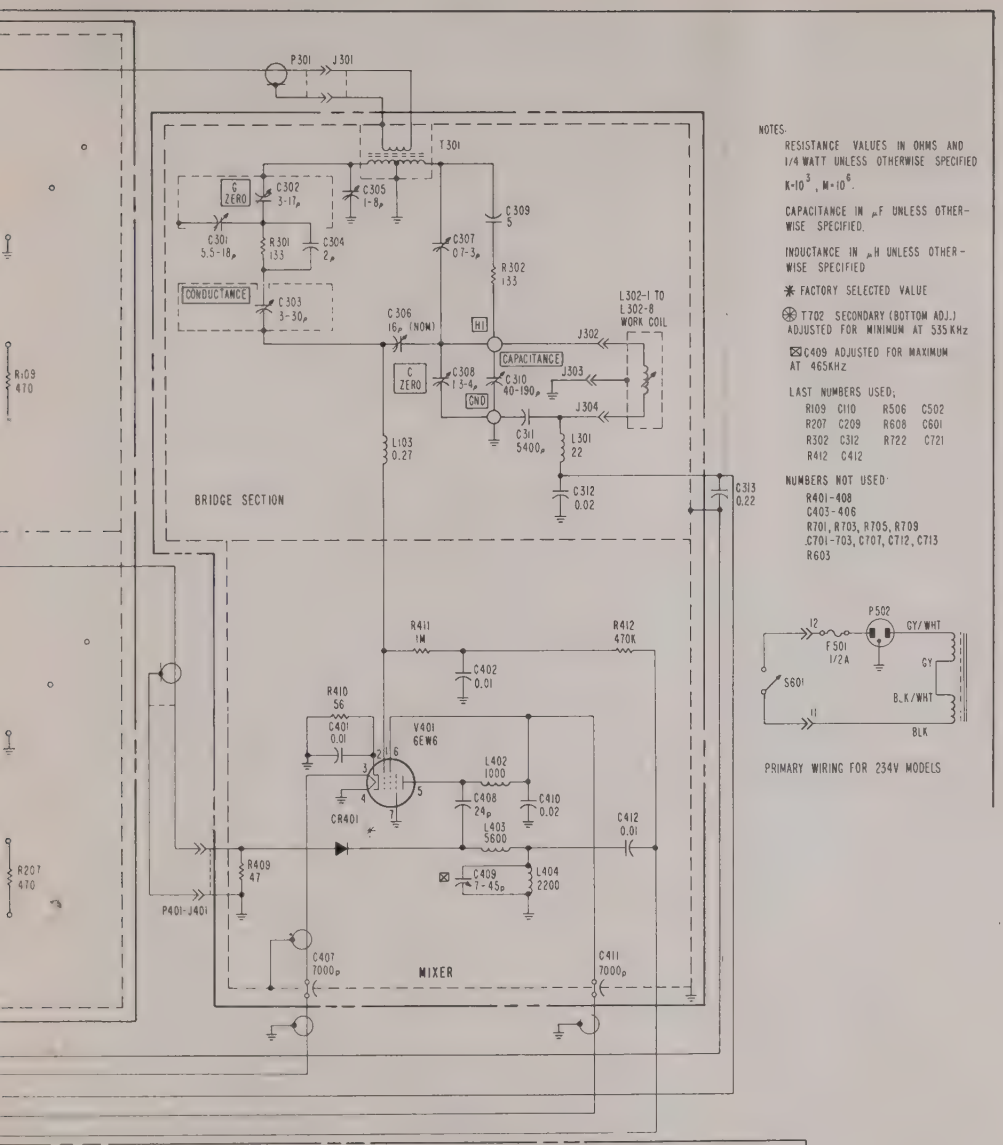
Reference		Description	BEC Part No.
M601	Meter	0-50 μA DC	554,140
R601	Resistor, Var.	10KΩ 2W	311,124
R602	" Var.	50KΩ 10% 1/10W	311,120
R608	"	1KΩ 5% 1/4W	300,082
R604	"	33KΩ 5% 1W	302,137
R605	"	3.6KΩ 5% 1/2W	301,100
R606	"	15KΩ 5% 1/2W	301,115
R607	"	50KΩ 5% 10 turn	311,198
S601	Switch, toggle		465,106
S602	"	4 pole 5 position	466,161

Amplifier - Detector

C704	Capacitor	0.05 μF 200V	230,117
C705	"	0.01 μF 200V	230,107
C706	"	0.05 μF 200V	230,117
C708	"	0.05 μF 200V	230,117
C709	"	0.05 μF 200V	230,117
C710	"	0.01 μF 200V	230,107
C711	"	0.05 μF 200V	230,117
C714	"	0.01 μF 200V	230,107
C715	"	0.01 μF 200V	230,107
C716	"	0.01 μF 100	224,119
C717	"	0.02 μF 500	224,118
C718	"	0.01 μF 100V	224,119
C719	"	56 pF 5% 500V	200,030
C720	"	24 pF 5% 500V	200,009
C721	"	0.02 μF 500V	224,118
CR701	Diode	1N58A	530,021
CR702	"	1N251	530,043
CR703	"	SG3113	530,040
L701	Choke	180,000 μH 20%	400,140
R702	Resistor	470KΩ 5% 1/2W	301,151
R704	"	470Ω 5% 1/2W	301,079
R706	"	470Ω 5% 1/2W	301,079
R707	"	100KΩ 5% 1/2W	301,135
R708	"	470Ω 5% 1/2W	301,079
R710	"	470KΩ 5% 1/2W	301,151
R711	"	180Ω 5% 1/2W	301,069
R712	"	470Ω 5% 1/2W	301,079
R713	"	470Ω 5% 1/2W	301,079

Reference		Description			BEC Part No.
R714	Resistor	68KΩ	5%	1/2W	301,131
R715	"	470Ω	5%	1/2W	301,079
R716	"	470KΩ	5%	1/2W	301,151
R717	"	47KΩ	5%	1/2W	301,127
R718	"	470K	5%	1/2W	301,151
R719	"	22K	5%	1/2W	301,119
R720	"	220K	5%	1/2W	301,143
R721	"	470K	5%	1/2W	301,151
R722	"	2.7M	5%	1/2W	301,169
T701	Transformer, IF				410,017
T702	"				410,017
V701	Tube	6AU6			5266BA6
V702	"	6CF6			5266CF6


TEST OSCILLATOR
LOCAL OSCILLATOR
POWER SUPPLY
FRONT PANEL
FREQUENCY Mc
RF LEVEL
TO ALL INDICATED FRONT PANEL GROUNDS
SENSITIVITY
BIAS METER
DC BIAS
INTERNAL
EXTERNAL
NULL INDICATOR



NOTES:

RESISTANCE VALUES IN OHMS AND 1/4 WATT UNLESS OTHERWISE SPECIFIED

K-10^3, M-10^6.

CAPACITANCE IN μF UNLESS OTHERWISE SPECIFIED.

INDUCTANCE IN μH UNLESS OTHERWISE SPECIFIED

✱ FACTORY SELECTED VALUE

⊛ T702 SECONDARY (BOTTOM ADJ.) ADJUSTED FOR MINIMUM AT 535 KHz

⊠ C409 ADJUSTED FOR MAXIMUM AT 465KHz

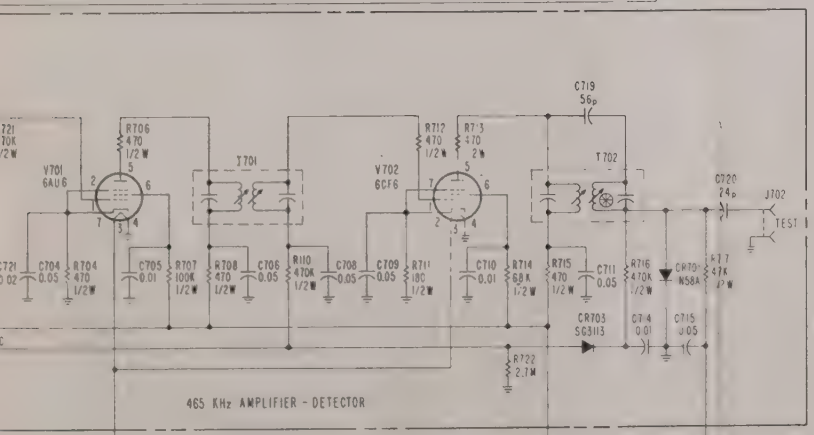
LAST NUMBERS USED:

R109	C110	R506	C502
R207	C209	R608	C601
R302	C312	R722	C721
R412	C412		

NUMBERS NOT USED:

R401-408
C403-406
R701, R703, R705, R709
C701-703, C707, C712, C713
R603

PRIMARY WIRING FOR 234V MODELS



Schematic diagram for Model 33A

Dwg. No. 830241 E

Serial Number 310 and above

Warranty

Boonton Electronics Corporation warrants its products to the original Purchaser to be free from defects in material and workmanship and to operate within applicable specifications for a period of one year from date of shipment, provided they are used under normal operating conditions. This warranty does not apply to vacuum tubes that have given normal service, to sealed assemblies which have been opened, or to any item which has been repaired or altered without our authorization.

We will repair or, at our option, replace at no charge any of our products which are found to be defective under the terms of this warranty.

SHIPPING INSTRUCTIONS

If it becomes necessary to ship the instrument, the following steps should be followed:

a. Wrap the instrument with heavy wrapping paper and seal the seams with gummed tape. Place in fibreboard carton large enough to permit three inches of soft packing material between instrument and sides of box.

b. Alternatively Boonton Electronics will provide an appropriate shipping container and packing materials at nominal cost. These may be obtained by writing to the Sales Department, Boonton Electronics Corporation, Route 287 at Smith Rd., Parsippany, N. J. 07054.

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